Cold and Crowded

The Early Childhood Education Environments Study

Mike Bedford

A thesis submitted for the degree of

Doctor of Philosophy

at the University of Otago,

Wellington, New Zealand

Abstract

Background

In recent decades New Zealand has seen a growth in the use of childcare as a weekday living environment for children under five years old, with an increasing proportion of children attending, and children attending for longer hours. For children in early education or care, New Zealand has one of the lower allocations of indoor activity space per child in the OECD, at 2.5m^2 per child. The New Zealand minimum indoor temperature requirement for these environments is 16ºC, the lowest found in a search of English-language statutes and recommendations. With one exception, all other recommendations or requirements found were 18ºC or more. New Zealand research has found a positive association between higher rates of respiratory and gastrointestinal infections, and colder temperatures and crowding in dwellings, while four studies outside New Zealand reported negative association between illness rates and greater area per child in childcare. Viral infectivity has been shown to decrease with higher environmental temperatures.

Methods

A 22-week observational cohort study was conducted in winter-spring 2017 measuring temperatures, humidity, child illness rates and rates of absence from childcare, and consequent parental absence from work. The study involved 22 full-day childcare centres, and a final cohort for statistical analysis of 221 children aged two to five years old. The study geographic area was the Hutt Valley and nearby suburbs, in the Wellington region of New Zealand. Indoor temperature and humidity were measured at 15-minute intervals, while activity space per child was calculated from floor area measurement and Ministry of Education daily attendance data. Symptomatic illness data and absence data were obtained from website-based reports entered by parents. Data were analysed by generalised linear mixed modelling to account for clustering by childcare centre, to generate rate ratios (RR) of child-days sick in relation to environmental variables.

Results

The study found a significant negative relationship between increased indoor temperatures in childcare and child-days sick. For each degree increase in the median winter indoor temperatures, risk was reduced by 28%, RR = 0.721 (95% CI: 0.563 to 0.924). The association was significant across the second and third quartile temperature ranges, which were from 15.2^{o}C to 20.8^{o}C. For each percentage point of time spent under 18^{o}C, risk of children being away sick increased 1.5% (95% CI: 0.6% to 2.4%). The modelling controlled for mould in the child's home, ethnicity, use of a Community Services Card (a proxy for low income), and child age. The study also found high levels of non-compliance with minimum temperature and minimum area-per-child legal requirements. Surprisingly, the analysis indicated an association between increased risk of illness and more square metres of space per child: winter-spring RR 2.132 (95% CI:1.222 to 3.720). The result was affected by multicollinearity however, and potential confounding between space per child and temperature. After removing one environment that was an outlier for illness rates and space per child, the winter result became statistically insignificant (95% CI: 0.904 to 1.376), but there was little change in the winter-spring result. This result is contrary to the four studies mentioned above, while the only other comparable study found in the literature review found no association between area per child and illness rates.

Conclusions

The results support an increase in the minimum indoor temperature requirement to 18^{o}C, in line with WHO recommendations. The study also indicates a need to improve compliance with environmental legal minima in the New Zealand childcare sector. The analysis suggested that more space per child is a risk for illness, but this result is inconsistent with other studies, and lacks a direct mechanism for causation. The area per child result may have arisen through use of daily attendance data to generate a proxy measurement for space per child, an approach that is unable to distinguish time spent outdoors from time spent outdoors at the childcare centre.

Acknowledgements

There are many people who have made the initial venture into this PhD and its completion possible.

Firstly, my thanks to my supervisory team, Lucy Telfar-Barnard, Julie Bennett, Caroline Shorter and Julian Crane, and my University of Otago advisors Philippa Howden-Chapman and Michael Baker. Their attention to detail, and their help outside reasonable hours when time became a pressure was so much appreciated.

My thanks to Manfred Plagmann of BRANZ for technical advice and rescuing me in times of equipment crisis. Thanks also to Helen Viggers for HOBO help. Dalice Sim provided guidance on use of IBM SPSS and univariate analysis, while Nevil Pierse provided advice on generalised linear mixed modelling using the statistical analysis package 'R'.

I want to acknowledge the support of Ramona Tiatia and Yun Sung for providing both the resources and technical knowledge for the development of the website used for illness data collection.

The University of Otago Wellington librarians have been consistently friendly and helpful (which counts for so much if you're a bit stressed), and I especially want to thank all the wonderful people University of Otago IT services team, especially Sandi Jull for being unfailingly cheerful and very helpful. I've also so much appreciated the support and encouragement from Hera Cook, Ruth Cunningham, Kim Nathan and Libby Grant – and many others at the Wellington campus.

Susan Bates has been an outstanding support and inspiration, as a person equally passionate and concerned about the wellbeing of children in New Zealand early childhood education services.

Very special thanks to my wonderful sister Lynda Muir, without whom the PhD wouldn't have been possible, and who donated the services of my equally wonderful friend Corinna Lines, who provided super-detailed proofreading via Lynda's plain English company, Write.

This research was undertaken with approval from the Health and Disability Ethics Committee of the New Zealand Ministry of Health (Reference: 16/CEN/69/AM01), and was supported with funding from BRANZ Incorporated (which administers the New Zealand building research levy).

Preface

Childcare and early childhood education in New Zealand – a societal change

In the past few decades New Zealand, along with many other countries, has moved away from home as the primary daytime environment for children under five years old, towards increasing levels of institutional care. Over the same period, there has been a growing appreciation of early childhood education as beneficial for children, and the promotion of early childhood teaching as a profession [2]. Emphasis on the importance of early education as not only inherently beneficial for children, but also as a necessary component of childcare, has resulted in all early childhood education and group care provision being brought under the jurisdiction of the Ministry of Education, by means of the Education Amendment Act 1990. In the 1990 Act, the umbrella term 'Early Childhood Centre' meant premises used for the non-parental education or care of three or more children under six years old, including the (then) fully state-funded Free Kindergartens, private 'preschools', childcare centres and community crèches. 1990 also saw an incremental plan developed for common qualification requirements for childcare and kindergarten services [3].

1996 saw the implementation of the human development model and curriculum guidelines *Te Whāriki* [1], which were made compulsory throughout the early childhood education (ECE) and care sector.

During this time, but especially during the period following the 1990s, commercial childcare also became a major factor in the ECE and care sector, with organisations such as the Early Childhood Council (ECC) representing, and lobbying for, business interests [4, 5]. Increasing house prices since the 1990s placed strain on household incomes (see Section 2.3), making full day care for children under five years old no longer a choice, but an economic necessity for many parents.

My own involvement with the ECE and care sector began in 1992 while working for Wellington Regional Public Health. I was responsible for investigating infectious disease outbreaks in the Wellington region, especially gastroenteritis, and in a separate, concurrent role, for the provision of licensing reports and advice to ECE centres. Within a year of undertaking this role, several aspects of the ECE sector had my attention:

- They had poor design features in relation to hygiene and heating
- They were over-represented in outbreaks
- Teachers wanted information, and were willing to ‘do the right thing’, but seemed to have little knowledge of disease prevention.

One example was a centre that had just had a gastroenteritis outbreak. When I visited, they were supplementing their handbasins with a bowl of water on a table for children to wash their hands in before a meal. They did this because the minimum regulatory 1:15 ratio of handbasins to children meant that the handwashing routine took much too long. Rather than skip handwashing, they used the bowl, but without realising that they were likely to be increasing rather than reducing infection transfer risk.

A common design feature I observed in ECE centres at that time was the use of fan heaters as the main heating appliances, mounted high on walls for electrical safety. Unfortunately, most of these heaters were not designed for high mounting, and blew air horizontally across the upper air space (see Figure 1). I noticed that the rooms could be quite cold at child level, while at the same time teachers said they had high power costs and had difficulty heating the rooms.

Figure 1: Fan heater location in a childcare centre

(A note about Figure 1: At the time this photo was taken the heater was redundant, but it is an example of common heater location).

Other potential health issues in ECE and care were coming to my attention, as I realised the diversity in the sector, and the difference between centres designed (or buildings adapted) primarily for childcare according to minimum standards, and those that had been designed primarily for early education. The latter, such as kindergartens, Playcentres and some private centres, had spacious outdoor areas with natural spaces. Those with design based on minimum regulations often had small, poorly equipped outdoor areas, lacking grass or natural spaces, without room for a child to run. I began to appreciate the importance of adequate teacher to child ratios, to see that good ratios are important for the development of relationships, and that relationships could be critical to emotional health, especially for infants and toddlers. I was also aware, from hundreds of ECE centre visits, that visiting a centre on a rainy day could be very unpleasant because of the noise and crowding inside the building. Was that really conducive to care and education? Thinking about my observations across the ECE sector, I came to the conclusion that while New Zealand had done very well with curriculum concepts, pedagogy and emphasis on qualified teachers, neither teacher training nor centre design paid sufficient attention to child wellbeing. It seemed to me that some environments, rather than being beneficial to children, might be actively harmful.

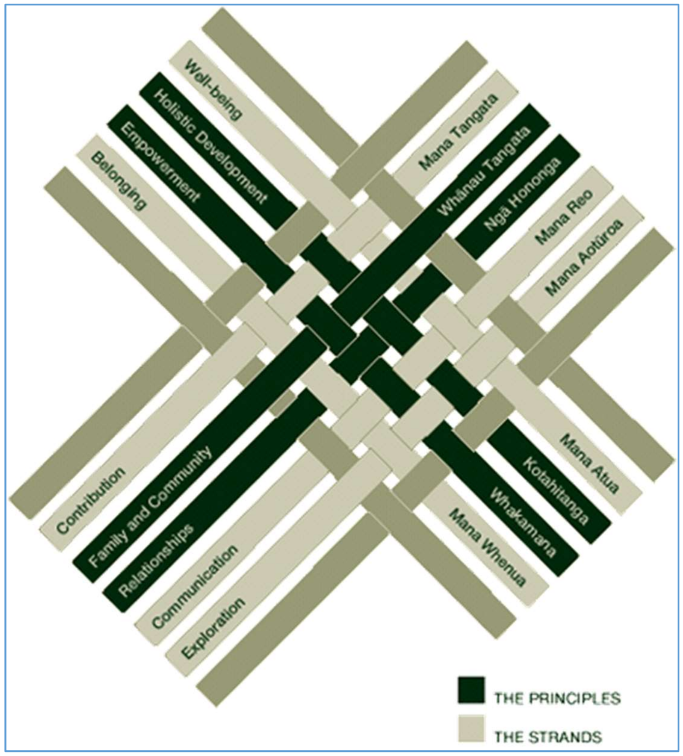
"If you design by regulation, you will get bad design – not maybe, definitely"

Over the following two decades I was employed by Wellington Regional Public Health, which worked to increase handwashing facilities in ECE centres, and to train teachers in understanding of disease transmission (personal involvement, 1992–2009). During this period the Public Health Unit also developed a health resource, published by the Ministry of Health as *Nga Kupu Oranga, Healthy Messages* [6], originally designed to address many problems with lack of knowledge and poor design. Unfortunately, much of the information developed by the Public Health Unit was deleted from the resource by the Ministry of Health before publication, including all of the design information. By 2000 the Public Health Unit was using its own advisory pack for centre developers and architects that stated, "Don't design by legislative compliance, but do a regulatory check before you spend any money" [7], and saying verbally, "If you design by regulation, you will get bad design – not maybe, definitely." We urged owners not to work to minimum space, as we were concerned about the potential health implications of crowding: noise, stress and infections.

"You do health, we do education – I really don't see the connection"

In a 2001 conversation with the then CEO of Early Childhood Development (ECD), an advisory branch of the Ministry of Education for ECE, I was told, "You do health, we do education – I really don't see the connection" (personal communication by phone). This statement was all the more remarkable given that the first of the five 'strands' (curriculum themes) in *Te Whāriki* is 'well-being' (see Figure 2), defined as "The health and well-being of the child are protected and nurtured."

Figure 2: Te Whāriki – illustration from the 1996 version [1]



In 2002, an approach to the Ministry of Health for the establishment of a national ECE wellbeing programme, endorsed by the New Zealand Childcare Association, was declined. The Chief Advisor for Child Health Strategy (Ministry of Health) replied with an apology saying, "I'm sorry, I can't find anyone else interested [in the Ministry of Health]" (personal communication by email, 2002).

In a discussion with the Ministry of Health in April 2016 about a revision of *Nga Kupu Oranga*, I was told that, "The Ministry of Health is not going to tell the education sector about design" (personal communication by phone). Design information was again to be excluded from the health resource.

I came to the conclusion that despite the work of a few individuals in New Zealand Public Health Units since the early 1990s, a conceptual and administrative gap between the education and health sectors was proving to be an obstacle to achieving design and regulatory improvements for ECE centre environments.

On the bright side – making the connection

In 2016, Auckland University of Technology hosted the first-ever New Zealand conference for wellbeing in early childhood education: *Mana Atua 2016.* The conference was a step towards building recognition of the essential connection between wellbeing and education: a link that matters from early education to tertiary education, but is perhaps most important in the earliest years. ‘Whāriki’ means ‘weaving’, and the implication of the weaving model is clear – every strand and principle supports every other strand and principle. Wellbeing supports the whole curriculum: the whole of a person’s physical, mental and emotional development. The rest of the curriculum also supports wellbeing – children’s motivations and understanding, exploration and contribution.

One of the foundational principles of the Wellington Regional Public Health Programme developed in the 1990s was the use of curriculum-based Health Promotion approaches. It worked on the understanding that you can’t do health in early childhood education unless you understand early childhood education, and to do that, you have to understand children.
It was also a problem-solving approach, with an emphasis on Health Promotion rather than regulatory compliance, working in partnership with teachers and ECE organisations. Minimum regulatory standards were not considered to be automatically conducive to good health outcomes, or even to be acceptable from a public health perspective.

So much potential for good, but also for harm

It is important to acknowledge the work of early childhood teachers, and to recognise just how good early childhood education and care can be. While attending an ECE conference in the 1990s, I was enthralled by a presentation on the thinking and learning of children before two years old. I thought, “I love this – it’s absolutely fascinating, and beautiful.” I’ve seen so much brilliant and creative work with and from children, and some great environments. When I first read *Te Whāriki*, I called it the best government document I had ever seen, and I still do. *Te Whāriki* is Health Promotion on a silver platter: holistic, empowering and partnership-based. I’ve come to the conclusion that there is enormous scope both for good and for harm in our early education and care environments, and that they really deserve cross-sector attention.

Getting the empirical data – emerging research

One of the weaknesses in the approaches to the Ministries of Health and Education was the lack of empirical New Zealand data. We had no data adequate to describe operational conditions in New Zealand ECE environments, or children's infection rates. Are New Zealand ECE centres really cold and crowded? Maybe centres are actually working to better than regulation standards? Do children actually get sick much, and if so, do conditions in ECE centres have anything to do with it? Is there any link between ECE temperatures, crowding, or maybe ventilation systems and illness?

This thesis seeks to answer just a few of the many questions about the health impact (for better or worse) of New Zealand ECE environments. Its focus is space per child, temperatures and humidity, alongside children's illness rates and consequent parental absences from work. While I have been researching these aspects, others in New Zealand have been investigating activity flow through spaces, air quality, teacher health and wellbeing, and children's nutrition and physical activity in ECE centres.

In its research method this thesis is clearly quantitative, but the implications are very much qualitative. It has to do with quality of life, not only for future years, but in the moment, for children under five years old.

Table of Contents

Abstract i

Acknowledgements iii

Preface v

Table of Contents xi

List of Figures xix

List of Tables xxii

List of Abbreviations xxiv

Glossary of early care and education terminology xxv

1 Introduction and thesis outline 1

1.1 Thesis aims and hypothesis 1

1.2 Thesis overview 2

2 Current context: The ECE and care environment in New Zealand 4

2.1 Introduction 4

2.2 Types of Early Childhood Education Service in New Zealand 6

2.3 Changes in attendance by service type since 1993 – the move to full-day care 8

2.4 Licensing and inspection 10

2.5 Physical standards 11

2.5.1 Minimum space per child in New Zealand day care 11

2.5.2 Noise and sociological consequences of crowding, and secondary effects of stress 14

2.5.3 Minimum temperatures in New Zealand day care 14

2.5.4 Regulation changes – from emphasis on health and safety to emphasis on qualifications – for the loss of health and safety? 16

2.6 Conflicting pressures and ideologies 18

2.7 Childcare as business 20

2.8 Air quality and ECE centre location 21

2.9 Possible blind spots in epidemiology and health policy 23

2.10 In the news – concerns about quality, temperatures and space 27

2.11 Summary 30

3 Literature Review 31

3.1 Overview and scope 31

3.1.1 Search terms 33
3.1.2 Subject and date filters 34
3.1.3 Title inclusion 35

3.2 Part One (two components) – association between childcare attendance and infection 36

3.2.1 Respiratory infections, asthma, and ear infections 38
3.2.2 Gastrointestinal infections 40
3.2.3 Acquired resistance 43

3.3 Part One continued (two components) – environmental conditions 45

3.3.1 Crowding and group size 46
3.3.2 Temperature, humidity and meteorological conditions 48
3.3.3 Bacterial, viral, fungal and endotoxin environmental loading and transmission 51
3.3.4 Ventilation, CO_2 and stratification 54
3.3.5 Chemical and particulate effects 57
3.3.6 Hygiene, hands and fomites 59

3.4 Part Two (three components) – studies investigating early care and education .... physical environments with health outcome measures 62

3.4.1 The Environment and Health in Children's Day Care Centres Study – ENVIRH (Portugal) 62
3.4.2 Porto and Lisbon study of risk factors among children attending day care studies (Portugal) 66

3.4.3 Risk factors for gastroenteritis in child day care (Netherlands) ... 67
3.4.4 Health in day-care centres study (SIB) and subsequent ventilation study (Denmark) ... 68
3.4.5 The IECH study (Denmark) ... 69
3.4.6 Significance of playroom area for illness among children in day care centres (Denmark) ... 70
3.4.7 Oslo study – Respiratory health and day care centre characteristics (Norway) ... 71
3.4.8 Helsinki-1 study – Day care and home variables and child illnesses (Finland) ... 71
3.4.9 Temperature and illness outcome study (Germany) ... 73

3.5 Cost of ECE or childcare-attributable illnesses ... 73

3.6 Research in childcare settings ... 75

3.7 Summary ... 76

3.7.1 Two-component review findings (Part One) ... 76
3.7.2 Three-component review findings (Part Two) ... 78
3.7.3 Implications for further research ... 79

4 Methodology ... 80

4.1 Overview ... 80

4.2 Data sources ... 82

4.2.1 Existing data sources ... 82
4.2.2 Available data collection systems, safety, and security ... 83

4.3 Study population and recruitment ... 84

4.3.1 Population factors considered in study design ... 84
4.3.2 Power calculation and cohort size ... 85
4.3.3 Child cohort age range and exclusions ... 86
4.3.4 Variations in ECE hours and ethnicity ... 87
4.3.5 Cohort geographic area selection ... 88
4.3.6 Recruitment ... 90

4.4 Māori consultation ... 90

4.5 Illness and absence data collection options 90

4.5.1 Paper forms 91
4.5.2 Phone interviews 91
4.5.3 Website-based online data entry 91
4.5.4 Parent motivation and likely participation 93
4.5.5 Perceptions of confidentiality and anonymity 94

4.6 Other factors potentially influencing illness outcomes 95

4.7 Summary 96

5 ECEE Study Methods 98

5.1 Study population and recruitment 98

5.1.1 Childcare centre enrolment 98
5.1.2 Child enrolment process (Figure 20) 99

5.2 Illness and absence data collection, child and home questionnaires 101

5.2.1 Website pre-testing 101
5.2.2 Website structure and implementation 101
5.2.3 Threshold for illness data collection 102
5.2.4 Childcare centre notifications of absence due to illness 102
5.2.5 Initial questionnaires for parents and introduction to the website process 103
5.2.6 Illness questionnaire process (parent data entry) 104
5.2.1 Tracking of illness reports 106

5.3 Measured environmental characteristics of childcare centres 108

5.3.1 Area per person 108
5.3.2 Temperature and relative humidity monitoring 109
5.3.3 Wireless Tag system, internet security and electronic device safety 109
5.3.4 Tag calibration and performance 111
5.3.5 CO_2 concentrations 115

5.4 Observed and teacher-reported environmental attributes and practices ... 115

5.4.1 Centre preliminary visits, questionnaire scope and pre-testing ... 115
5.4.2 Child handwashing facilities and practices in childcare centres ... 117
5.4.3 Nappy change practice ... 118
5.4.4 Disinfection and cleaning ... 118
5.4.5 Comfort toys and playdough ... 119

5.5 Ethics approval and confidentiality ... 119

5.6 Analysis ... 121

5.6.1 Overview of analysis steps ... 121
5.6.2 Childcare centre temperature and humidity data ... 122
5.6.3 Childcare centre CO_2 data ... 123
5.6.4 ECE centre reported and observational data ... 123
5.6.5 Child age, ethnicity and health data, and home environment data ... 125
5.6.6 Linear regression analysis ... 126

5.7 Research process timelines ... 129

6 Results and analysis ... 131

6.1 Data collection systems – participation and performance ... 131

6.1.1 ECE centre enrolments and participation ... 131
6.1.2 Child enrolments and participation ... 132
6.1.3 Website training, data entry and completion ... 133
6.1.4 Data cleaning ... 135
6.1.5 Childcare centre returns and sick child attendance ... 135
6.1.6 Researcher time demand for parent and centre communication ... 135
6.1.7 Participant fatigue and teacher / manager stress ... 136
6.1.8 Wireless Tags for temperature and RH monitoring ... 137

6.2 Sample populations ... 138

6.2.1 Child cohort demography ... 138
6.2.2 Child cohort childcare attendance data ... 142

6.2.3 Child health history 144
6.2.4 Child cohort home environments 146
6.2.5 Childcare building, heating and ventilation characteristics 150
6.2.6 Childcare centre heating and ventilation 150
6.2.7 Childcare centre hygiene and sick child management 153

6.3 Illnesses and absences 156

6.3.1 Illnesses and absences by individual child 156
6.3.2 Seasonal differences 157
6.3.3 Child and parent illnesses and absence outcomes as days per week of attendance 161
6.3.4 Illness rates by childcare centre 161

6.4 Childcare environmental conditions 162

6.4.1 Area per child results 162
6.4.2 Temperature results 164
6.4.3 Relative humidity results 168
6.4.4 Absolute humidity results 171
6.4.5 CO_2 measurements 172

6.5 Correlation of illness rates with environmental conditions 175

6.5.1 Univariate analysis of child and environmental covariates – screening for inclusion in a generalised linear model 175
6.5.2 Space per child and illness rates – generalised linear mixed modelling 179
6.5.3 Multicollinearity 182
6.5.4 Temperature and illness rates 184
6.5.5 Analysis by symptom group 187

6.6 Summary 188

6.6.1 Study methods and participation 188
6.6.2 Sample populations 188
6.6.3 Child illness outcomes, time away from childcare and parent lost work time . 189
6.6.4 Childcare centre conditions and compliance with regulations 190
6.6.5 Correlation of illness rates with environmental conditions 190

7 Discussion and conclusions 192

7.1 Environmental conditions 193

7.2 Illnesses and absences 195

7.3 Illnesses and indoor space per child 197

7.4 Illnesses and indoor temperatures and humidity 198

7.5 Other variables: Child age, starting age in care, home conditions 201

7.6 Limitations 202

7.6.1 Study power 202
7.6.2 Limitations of environmental measurements 203
7.6.3 Limitations of illness data 204
7.6.4 Limitations of home data 205
7.6.5 Sample skewing and selection bias 205
7.6.6 Centre type 206

7.7 Study methods 206

7.7.1 Illness data collection from parents 206
7.7.2 Environmental monitoring 207
7.7.3 Centre manager stress and respondent fatigue – implications for study design and duration 208
7.7.4 Management of confidentiality for findings of non-compliance 209

7.8 Conclusions – hypothesis and study methods 209

7.9 ECE sector policy developments 210

8 Recommendations for research, and for health, education and employment policy 212

8.1 Key recommendations for policy 212

8.2 Improvements to the ECEE study methods 213

8.3 Research practice in the ECE setting 214

8.4 Research topics 215

8.5 ECE Strategic Plan 2019–29 216

References 217

Appendix 1: Extract from Regional Public Health Submission – Draft Criteria for Licensing of ECE Services ... 233

Appendix 2: Regional Public Health Comments on the 2007 Ministry of Education 'Design and Build' Project Draft Plans ... 243

Appendix 3: New Zealand Schedule of Notifiable Diseases ... 245

Appendix 4: Examples of Climate Variations in Wellington Regional Suburbs ... 247

Appendix 5: Online data entry literature review ... 249

Appendix 6: Childcare centre and staff introduction ... 253

Appendix 7: Childcare centre enrolment form ... 256

Appendix 8: Childcare centre poster ... 257

Appendix 9: Enrolment pack for parents ... 258

Appendix 10: Website pages ... 264

Appendix 11: Childcare centre Phase 1 questionnaire ... 282

Appendix 12: Example of centre weekly email – sick children ... 297

Appendix 13: Tag deployment ... 298

Appendix 14: Prior illness frequency histograms ... 300

Appendix 15: Changes in standard error with inclusion of predictor variables in the GLMM for space per child and child sick days. ... 304

Appendix 16: Recommendations for the Draft 10 year Strategic Plan for Early Childhood Education ... 305

List of Figures

Figure 1: Fan heater location in a childcare centre vi

Figure 2: Te Whāriki – illustration from the 1996 version viii

Figure 3: ECE Service attendance by age, reproduced from *Understanding attendance; results from the 2017 Early Childhood Education census* 4

Figure 4: Percentage of attendees by number of hours per week, reproduced from *Understanding attendance; results from the 2017 Early Childhood Education census* 6

Figure 5: Attendance at an ECE Service by service type, 2000–2017 9

Figure 6: Housing cost in relation to disposable income 1988–2015, reproduced from *Social Indicators*. Stats NZ website 10

Figure 7: OECD comparison of regulated minimum space per child in ECE and care centres, reproduced from OECD.org 12

Figure 8: Childcare space in a converted residential home 13

Figure 9: Heat pump located next to the door to the outside area in a childcare centre 16

Figure 10: Childcare as business 20

Figure 11: Location of childcare centres in a high-traffic commercial location 22

Figure 12: "It is like factory farming for children" 27

Figure 13: Extract from Child Forum Website – "Freezing Cold Early Childhood Centre" .. 28

Figure 14: "Our kids are not getting enough space in childcare" 29

Figure 15: "Parents' revolt forces kindergarten backdown" 30

Figure 16: Literature search components 32

Figure 17: Inclusion of titles and abstracts 36

Figure 18: Carbon dioxide as an indicator of school classroom ventilation 56

Figure 19: Study geographic boundaries – Hutt Valley, Wainuiomata and Johnsonville-Newlands 89

Figure 20: Child cohort enrolment process 100

Figure 21: First illness phone call – website introduction and background questionnaires... 103

Figure 22: Start of Illness screen 105

Figure 23: Typical website process for illness questionnaires 107

Figure 24: Wireless Tag System.. 110

Figure 25: Re-setting the Tag Manager 111

Figure 26: Tag response 113

Figure 27: BRANZ comparison of Tag RH response with Tag modification 114

Figure 28: Tag modification... 115

Figure 29: Phase 1 research process timeline.. 129

Figure 30: Phase 2 research process timeline.. 130

Figure 31: Total enrolments and data entry completion 134

Figure 32: Child cohort ethnicity compared with Census data 139

Figure 33: Age in years at start.. 140

Figure 34: Combined annual household income 142

Figure 35: Attendance – hours per week.. 143

Figure 36: Attendance –total enrolled hours during the study period 143

Figure 37: Prior history of parentally reported wheezing in the previous 12 months 146

Figure 38: Bedrooms and occupancy... 147

Figure 39: Parents’ assessments of coldness, damp and mould in homes 148

Figure 40: Dampness or mould in the home 149

Figure 41: Childcare centre heating systems... 152

Figure 42: Centre manager-reported ventilation using doors and windows 153

Figure 43: Sick child management 155

Figure 44: Sick days per child by childcare environment ID, winter-spring study period 162

Figure 45: Seasonal temperature profiles averaged across activity spaces.......................... 165

Figure 46: Difference in relative humidity in connected rooms ... 168

Figure 47: Seasonal relative humidity profiles by humidity band averaged across activity spaces ... 169

Figure 48: Seasonal indoor relative humidity by quartile averaged across activity spaces ... 170

Figure 49: Seasonal absolute humidity profiles by humidity band averaged across activity spaces ... 171

Figure 50: CO_2 levels in sleep rooms ... 172

Figure 51: CO_2 levels in an activity space for children under two years old ... 174

Figure 52: Half days sick per child (enrolled in the ECEE study) and percentage time at less than 2.0m^2 per child ... 181

Figure 53: Concurrent forecasts for a five-day spring period in October 2018, illustrating differences in the microclimates of Wellington and the Hutt Valley Suburbs. ... 247

Figure 54: One-day diurnal variations in temperature and wind speed for Wellington City, Lower Hutt, and Wainuiomata ... 248

Figure 55: Childcare centre consent form ... 256

Figure 56: Poster advertising the study to parents ... 257

Figure 57: Invitation to parents (A5, front of enrolment pack) ... 258

Figure 58: How the study works – the quick version (A5) ... 258

Figure 59: Parent information ... 259

Figure 60: Child enrolment form ... 261

Figure 61: Contact information for parents (A5) ... 263

Figure 62: Contact and ID number card (buisness card size) ... 263

List of Tables

Table 1: Average hours of attendance in ECE Services by age in 2017 5

Table 2: 1993 and 2002 Ministry of Education attendance data compared 8

Table 3: Requirements or recommendations for day care minimum indoor temperatures 15

Table 4: Search term combinations 34

Table 5: Studies involving environmental measures and health outcome measures 63

Table 6: Risk factors reported in three-component study findings 64

Table 7: Data sources 96

Table 8: Tag variance 112

Table 9: First round of childcare centre enrolments 131

Table 10: Second round of childcare centre enrolments 132

Table 11: Total numbers of children two years to five years old at each centre 133

Table 12: Child cohort gender compared with Ministry of Education record of enrolments 138

Table 13: Parent rating of child health at the commencement of the ECE study 144

Table 14: Child illness frequencies during the 12 months prior to the commencement of the study 145

Table 15: Heating system observations (Scale 1–5, from poor to excellent) 151

Table 16: Hand hygiene descriptors and scoring 154

Table 17: Total scores for hand hygiene practice across all environments 154

Table 18: Comparison of winter illness categories with spring illness categories 157

Table 19: Child illnesses and absences, and parent absences from work (winter-spring) 158

Table 20: Child illnesses and absences, and parent absences from work (winter only) 159

Table 21: Child illnesses and absences, and parent absences from work (spring only) 160

Table 22: Impact of illnesses in days per week 161

Table 23: Legal compliance and percentage of time by area per child threshold 163

Table 24: Space allocation by quartile 164

Table 25: Lower Hutt and Wainuomata winter and spring temperatures 167

Table 26: Dry weekdays during the study period 167

Table 27: Univariate regression for winter sick days per child as an outcome – centre environment variables 176

Table 28: Poisson univariate regression for winter child sick days as an outcome – child variables and home environment variables, with childcare centre as a random effect 177

Table 29: GLMM results for child sick days and minimum m^2 per child 180

Table 30: GLMM results for child sick days and minimum m^2 per child, excluding Environment 12.1 182

Table 31: Correlations between predictor variables 183

Table 32: GLMM results for winter child sick days and temperature by quartile 184

Table 33: GLMM results for winter child sick days and median temperature, excluding 'Age at start of study'. 185

Table 34: GLMM results for winter child sick days and temperature by temperature threshold, including space per child 186

Table 35: Temperature ranges for temperature quartiles in relation to sick days 187

Table 36: Initial search phrases and results from Scopus – title and abstract search 249

List of Abbreviations

AH	Absolute humidity
AOM	Acute otitis media
AOR	Adjusted odds ratio
ARD	Acute respiratory disease
CI	Confidence interval
ECC	Early Childhood Council
ECE	Early childhood education
GE	Gastroenteritis
GLM	Generalised linear model
GLMM	Generalised linear mixed model
HDEC	Health and disability ethics committee
LRTI	Lower respiratory tract infection
OM	Otitis media
OME	Otitis media with effusion
OR	Odds ratio
$PM_{2.5}$	2.5 micron particulates
PM_{10}	10 micron particulates
RH	Relative humidity
RR	Rate ratio
RSV	Respiratory syncytial virus
TVOC	Total volatile organic compound
URTI	Upper respiratory tract infection
VOC	Volatile organic compound

Glossary of early care and education terminology

A number of terms can be used to denote all or parts of the early care and education sector. For consistency and ease of reading, terms will be used in this thesis as defined below.

Early childhood education (ECE)

The term 'early childhood education' has been used in New Zealand in a broad sense to denote:

- The pedagogy and practice of education for children under five years old
- Any early childhood education and care service, including childcare
- The whole of the early education and care sector.

In this thesis the term is used to denote the pedagogy and practice, as distinct from day care provision and may be abbreviated to *ECE*.

Early childhood education and care centre, or early childhood centre

The term 'early childhood education and care centre' is defined in the Education Act S.310 as:

> ...premises used regularly for the education or care of 3 or more children (not being children of the persons providing the education or care, or children enrolled at a school being provided with education or care before or after school) under the age of 6—
> (a) by the day or part of a day; but
> (b) not for any continuous period of more than 7 days.

In this thesis the term is abbreviated to *early education and care centre* or just *centre*.

Early childhood service

The term ‘early childhood service’ is defined in the Education Act S.309 as:

> ...an early childhood education and care centre, home-based education and care service, or hospital-based education and care service.

In common practice, and in this thesis, the distinction between the ‘early childhood centre’ (above) and ‘early childhood service’ is the distinction between the premises (centre) and the organisation as a whole (service).

Childcare

The term ‘childcare’ is used commonly in international literature, and in New Zealand this term commonly refers to facilities established for the care of children while their parents are at work. The Ministry of Education category that covers childcare is ‘education and care services’, and these services are required to comply with the same regulations for facilities and trained teachers, and use the same curriculum and educational standards as other early education facilities.

Day care

‘Day care’ is a common term used in international literature, equating to ‘childcare’. The term is uncommon in the naming of New Zealand early childhood services, with very few facilities using the term ‘day care’ in their name. ‘Childcare’ is used in preference, but it is also diminishing in use, with educational terms such as ‘early learning centre’ being favoured.

Preschool

This was the most common term for early education or care found in the literature search, and is used in New Zealand in the naming of some ECE services, particularly for children in the three to four year age range, as opposed to care for infants and toddlers.

Sessional early childhood education

This term is derived from the ‘sessional’ category of licence defined in the Education Act S.3, and in this thesis refers to early childhood education for a maximum of four hours per day. In New Zealand, sessional ECE has typically had an education rather than childcare emphasis, with examples being Playcentre and sessional Free Kindergarten, typically for two to three hours in a morning or afternoon, three to five days per week.

Home-based care, and family day care

In New Zealand ‘home-based education and care’ is defined in the Education Act 1989 as provision of education or care for children in the children’s own home or another home, and is limited to a maximum of four children.

In other jurisdictions, home-based care or ‘family day care’ can have a range of definitions and maximum numbers, but the general principle is that of a small, family-sized group. For example, in Helsinki there are three types of ‘family day care’: family day care that takes place at the care provider’s home; ‘group family day care’; and ‘three-family day care’. Care in a provider’s own home is limited to five children (maximum four under five years old), while ‘group family day care’ is defined as “a maximum of eight children as well as two children who have begun preschool education or comprehensive school. If the group has three childminders, the maximum permissible number of children is 12” [8]. In the United States, maximum numbers of children range from four to eighteen, depending on ages, but less than twelve for children under five years old [9].

Crèche

‘Crèche’ is term that has been used in New Zealand for a range of childcare arrangements, from brief informal care of very young children while their parents/caregivers attended an event or activity (e.g. a church service or a swimming pool), through to licensed early childhood services. It is not a term used in New Zealand legislation, and has become increasingly uncommon in early childhood education and the naming of early childhood education services over the past three decades (from personal experience managing ECE public health programmes 1992–2009).

Group size

'Group size' is a term commonly used for the number of children sharing one space (a room or activity area) at one time, but may also apply to separately supervised groups in one area, indoors or outdoors. In one study reviewed in this thesis [10], the size of the childcare group was determined by asking the question, "How many children are usually cared for together, in the same group, at the same time? Do not include children in the entire school or programme." The term 'group size' is used in standards for early education and care internationally, but the term does not have a standard definition. Group size can be difficult to define, for example when children use some spaces intermittently, or when large spaces are partitioned with low-level barriers or furniture. Group size may need to be defined in relation to another factor, for example a physical factor such as discrete activity space, or possibly a sociological or pedagogical factor, such as the number engaged in activities together. In this thesis, 'group size' is used to describe the number of children sharing a bounded physical space, for example a room or rooms to which the children normally have access.

Undefined terms for early education and care used in referenced literature

Some terms used in documents by other authors may not be defined, and are therefore referred to or quoted in this thesis as used by the author(s), with inverted commas, for example, 'day nursery'.

1 Introduction and thesis outline

1.1 Thesis aims and hypothesis

The aims of this thesis are to:

1. Explore the literature related to environmental conditions in ECE centres, and to infections related to ECE and care attendance.
2. Measure occupancy rates, temperatures and humidity in ECE centres.
3. Measure illness rates for children in ECE centres, and absences due to illness.
4. Measure parental absences from work due to their child's illness.
5. Identify relationships between the environmental conditions, and illness and absence rates.

The thesis tests three hypotheses:

1. Crowding in childcare is associated with increased rates of child illness, child absence from childcare, and parental absence from work.
2. Lower indoor temperatures (below 18^{o}C) in childcare centres are associated with increased rates of child illness, child absence from childcare, and parental absence from work.
3. Indoor humidity has an association with the rates of child illness, child absence from childcare, and parental absence from work.

1.2 Thesis overview

Chapter 2 – Current context: The ECE and Care Environment in New Zealand

This chapter provides a background understanding of early childhood education and care in New Zealand, including types of ECE service, the regulatory environment, and in particular, aspects of the regulatory environment that may affect child and teacher health. It discusses drivers and ideologies influencing the ECE and care sector, and their potential effects on physical conditions. It also looks at gaps in epidemiology with respect to ECE and care. The chapter finishes with examples of ECE teachers' concerns about conditions in ECE and care, as reported in the New Zealand news media in recent years.

Chapter 3 – Literature review

The literature review looked for other research that measured associations between infection rates and physical conditions in childcare. The review also looked for research into associated factors that could influence infection rates in childcare, such as the age at which a child first attends childcare, hygiene practices in the centre, or the relationship between temperature and viral survival.

Chapter 4 – Methodology

There had not previously been any research in New Zealand collecting data describing crowding, temperature or humidity in ECE centres, or attempting to measure the relationship between these conditions and illness and absence rates. The methodology chapter describes the rationale and development of research methods used to test the hypotheses, including sample cohort size and makeup, potential data sources, and the advantages and disadvantages of potential data collection methods.

Chapter 5 – ECEE Study Methods

The Early Childhood Education Environments (ECEE) observational cohort study was conducted during June 2016 to November 2017. This chapter describes the data collection systems that were used in the study (including pre-testing and calibration, cohort enrolment, and measurement of variables). It describes methods used for temperature, humidity and CO_2 measurement, spatial and crowding measurements, and describes the parent-reported, website-based, symptomatic illness and absence data collection systems. It also describes the questionnaires used for child, home and childcare centre extraneous variables, as well as Māori consultation and ethics approval. It finishes with a description of data analysis methods.

Chapter 6 – Results and analysis

The results chapter describes the ECEE study childcare centre and child cohorts, and describes the data gathered during the study. It then provides an analysis of the data, looking for associations between the environmental factors specified in the hypotheses, and illness and absence outcomes.

Chapter 7 – Discussion

Chapter 7 discusses the validity and relevance of the study results, and the implications of the results given the current regulatory and ECE centre design environment in New Zealand. It describes the limitations of the study, potential cohort selection bias and generalisability. This chapter also discusses the effectiveness and reliability of the research methods, including the implementation of, and cohort participation in, the ECEE study.

Chapter 8 – Recommendations for research, and for health and education sector policy

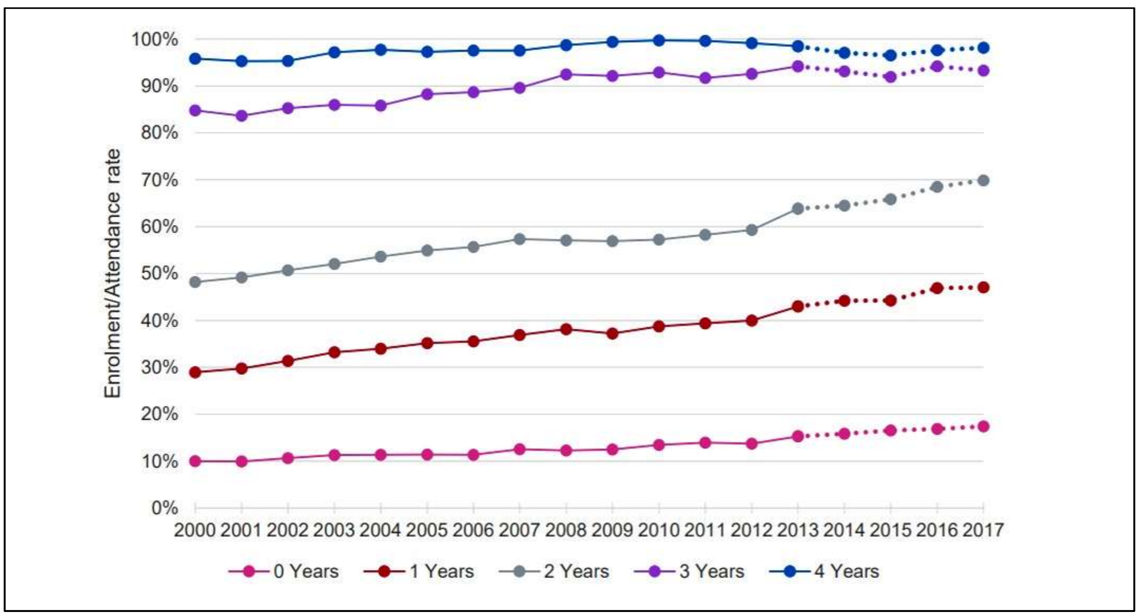
This chapter provides recommendations for research practice in the ECE sector, including improvements to the ECEE study methods. It also provides recommendations for a change to the regulated minimum temperature in New Zealand ECE environments, and makes suggestions for further research into ECE and care environmental conditions and illness rates.

2 Current context: The ECE and care environment in New Zealand

2.1 Introduction

In New Zealand the number of Early Childhood Education Services increased rapidly during the 1980s, with enrolments doubling between 1981 and 1989 [11]. From 1990 to 1997 enrolments increased a further 39%, while the number of Early Childhood Services increased 35.6%. By 1997, 143,540 children were enrolled in Early Childhood Centres in New Zealand (excluding home-based care and unlicensed playgroups), representing 51.3% of all children under the age of five.

Figure 3: ECE Service attendance by age, reproduced from *Understanding attendance; results from the 2017 Early Childhood Education census* [12]



Note: In 2014 the data collection system was changed to record attendance, rather than enrolment, hence the Ministry of Education has shown 'enrolment/attendance rate' on the y axis. The solid lines represent enrolment, while the dotted lines represent attendance.

During this time the New Zealand population increased 12.5% [13]. As at 2017, 189,079 children were enrolled in centre-based services. The increase in enrolments has been accompanied by a shift to full-day childcare rather than sessional early childhood education (see Section 2.3). Attendance rates range by age range from 17% for children under one year old, to 98% at four years of age (Figure 3).

Table 1 shows the average number of hours children spend in ECE Services [12].

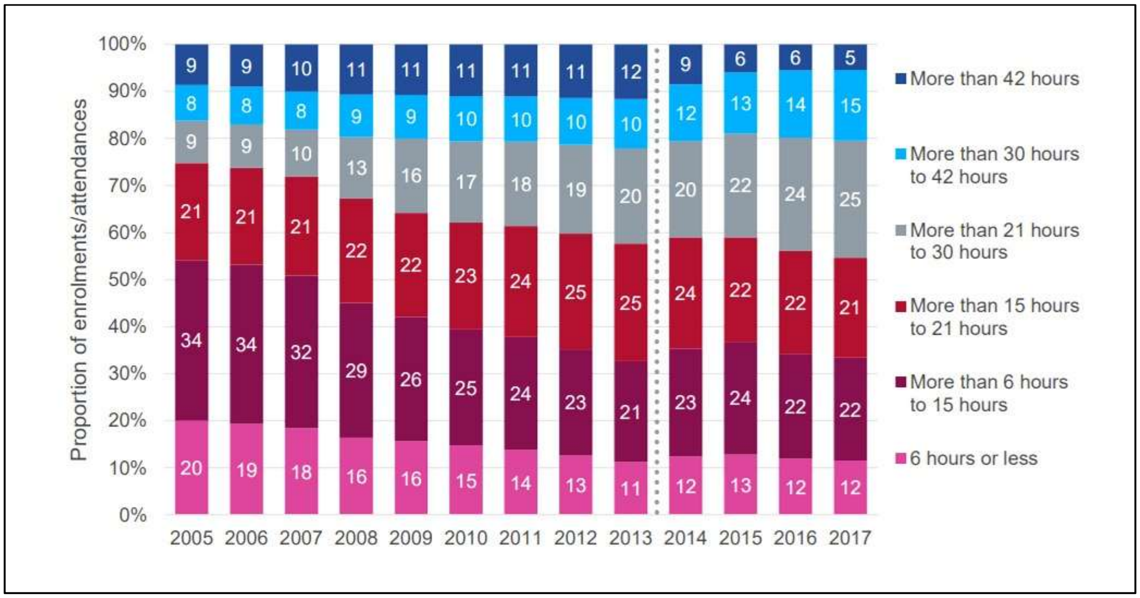
Table 1: Average hours of attendance in ECE Services by age in 2017

Age group	Average hours per week
Under 1 year old	16.8
1 year old	21.0
2 years old	20.3
3 years old	20.6
4 years old	21.7
5 years old	20.7

These are only averages though, and children can spend much longer hours in these environments, with 2017 data showing a shift towards longer hours since 2005. This increase in hours of attendance can be seen in the proportion of children spending more than 21 hours and more than 30 hours per week in an ECE Service (see Figure 4). The percentage of children in ECE Services for these hours will be greater than is indicated by Ministry of Education data, as some children are enrolled part-time in two services. This has the effect of inflating the number of enrolments recorded as being for shorter hours, and hiding long hours for individual children.

For some children under five years old, the early education and care environment has become a significant living environment, with a likelihood that the conditions in these environments will affect child health and wellbeing. Research into the impact of New Zealand home environments on health, especially by the Housing and Health Research Programme – He Kainga Oranga, has shown a clear relationship between low temperatures, dampness, crowding, and the incidence of respiratory and gastrointestinal infections [14, 15]. As at 2016 no research had been conducted to measure or identify relationships between these environmental conditions in early childhood centres, while New Zealand's minimum standards for temperatures and space per child give additional cause for concern.

Figure 4: Percentage of attendees by number of hours per week, reproduced from *Understanding attendance; results from the 2017 Early Childhood Education census* [12].



Note: In 2014 the data collection system was changed to record attendance, rather than enrolment, hence the Ministry of Education has shown 'enrolments/attendances' on the y axis.

2.2 Types of Early Childhood Education Service in New Zealand

New Zealand has a rich diversity of early education and care, with many educational and cultural philosophies and approaches to the design of environments for children. Within this diversity there are organisations specifically set up to benefit children, and others that are essentially commercial. The plethora of names used to describe these services can be confusing. The term 'kindergarten' describes a specific group of organisations, 'Free Kindergartens', with a history of sessional preschool ECE in centres with large outdoor spaces, but 'kindergarten' or derivatives such as 'kindy' are also widely used in names for minimum-standard commercial day care, such as 'Community Kindy'. Ministry of Education names for service types have changed over the years, moving from 'Early Childhood Centre' to Early Childhood Education Service' to 'Early Learning Service'. The result is that Ministry of Education categories for data do not necessarily match the category descriptions on its website.

Currently, the New Zealand Ministry of Education term "Early Childhood Education Service" includes the following categories:

- Centre-based services (includes 'education and care services' and Free Kindergartens)
- Playcentres
- Te Kōhanga Reo
- Home-based services
- Hospital ECE services
- Playgroups

The 'education and care' group includes services that correspond to terms such as 'day care', 'childcare', and 'preschool'. 'Free Kindergartens' are a special category that were historically fully government-funded, with teachers' salaries directly paid by the Ministry of Education, and no fees changed for attendance. The Free Kindergartens began as sessional centres, with children attending a maximum of three hours a day for three to five days per week. Children under two and a half years old could not be enrolled, and if they were under three years old, could only be enrolled in afternoon sessions (Kindergarten Regulations 1959). Changes to legislation, commercial drivers and parental needs in the current decade have seen Free Kindergarten Associations moving to continuous attendance for six to seven hours per day, five days per week. This move has been contentious, and while meeting the needs of some parents, it has seen a backlash from some parents wanting sessional rather than all-day care (see Section 2.10).

Playcentres are a New Zealand institution consisting of parent cooperatives, with early childhood education provided by the parents on a rostered basis. Parents receive early childhood teacher training provided by the Playcentre Federation, which is approved by the New Zealand Qualifications Authority (NZQA) [16]. Playcentres are strictly sessional. Playgroups are a different and more informal category that does not involve care other than by a child's own parent, and does not require training.

'Te Kōhanga Reo' translates to 'The Language Nest" and Te Kōhanga Reo are also unique to New Zealand. Te Kōhanga Reo were established with the primary aim of reviving Māori language and culture, starting at birth, and involving parents as well as trained teachers. Te

Kōhanga Reo are in other respects as diverse in operation as the 'education and care' grouping.

Home-based services are currently limited to care and education of up to four children, and operate in private residences, most often the family home of one of the attending children or the home of the educator providing the education and care. Educators are not necessarily qualified teachers; however, all educators work under the guidance and supervision of qualified (visiting) teachers.

Hospital-based services are those specially set up within hospitals to provide an early learning service to children in hospital due to illness. These services must also be led by qualified ECE teachers.

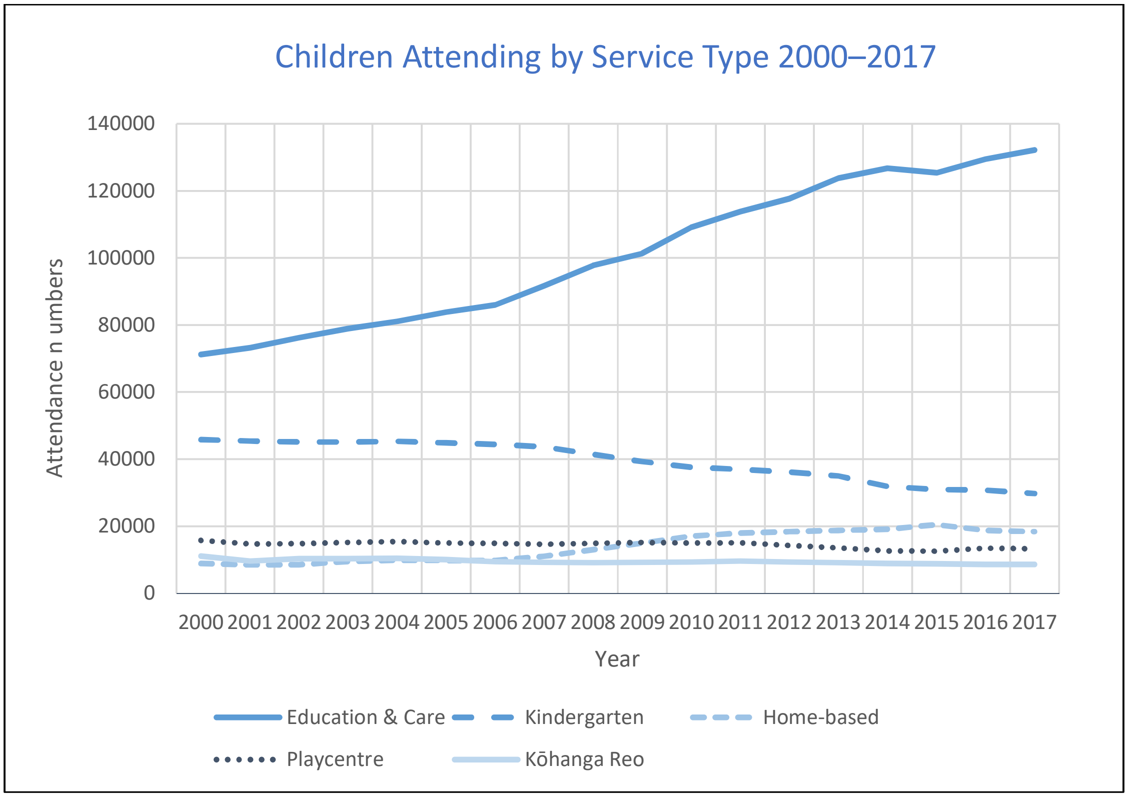
2.3 Changes in attendance by service type since 1993 – the move to full-day care

New Zealand has seen steady growth in the numbers and percentage of children involved in some form of early care or education since 1985, but this growth has not been uniform by service type. There has been a transition from the forms of early childhood education dominant in the mid-20th century, such as sessional Free Kindergarten and Playcentre, to full-day childcare. Information currently published by the Ministry of Education for centre type is shown in Figure 5, but the earlier Ministry of Education data in Table 2 shows changes by centre type for 1993–2002. In 2017 the majority of ECE services in New Zealand were 'education and care' with 2,558 services (55.6%). There were 658 Free Kindergartens (14.3%), 454 Kōhanga Reo (9.9%), 476 home-based services (10.3%), and 421 Playcentres (9.2%) [17].

Table 2: 1993 and 2002 Ministry of Education attendance data compared [18, 19]

	Enrolments		
Centre type	1993	2002	% change
Education and care	45,158	76,246	+69%
Free Kindergarten	46,030	45,169	-2%
Home-based	4,907	8,591	+75%
Playcentre	21,540	14,879	-31%
Te Kōhanga Reo	14,514	10,389	-28%

Figure 5: Attendance at an ECE Service by service type, 2000–2017 [20].

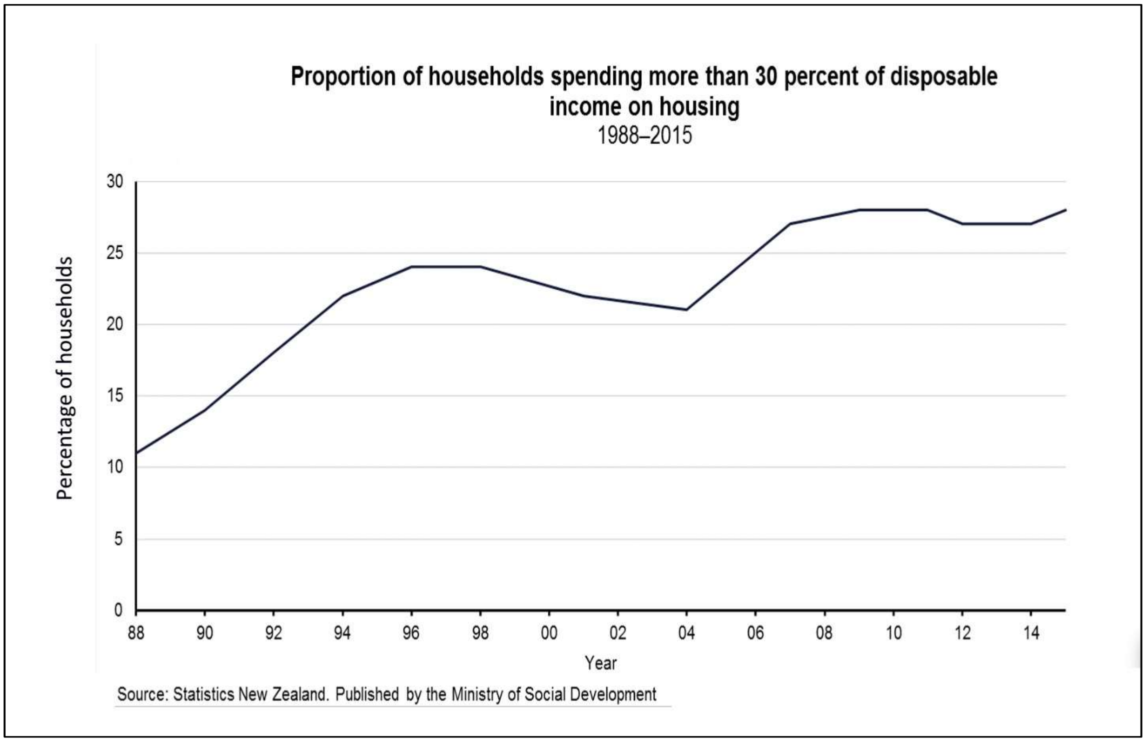


The changes in attendance by service type reflect changing work patterns and demands on New Zealand parents. New Zealand has seen a pattern of increasing housing cost relative to income over the past three decades, increasing the need for parents to work while their children are very young (Figure 6). There is evidence to show that families are most economically vulnerable when new children arrive, and financial pressure is frequently mentioned as a key reason for returning to work, in some cases earlier than desired by some parents [21].

Sessional early childhood service attendance is not compatible with full-time work for a solo parent or two parents, unless mixed-care arrangements are used (sessional ECE plus childcare for extra hours).

Paid parental leave increased from 18 weeks to 22 weeks in July 2018, and the New Zealand Government has announced an extension to 26 weeks in mid-2020 [22]. While this will assist families during the first months of a child's life, the pressure to use childcare will remain after the first six months.

Figure 6: Housing cost in relation to disposable income 1988–2015, reproduced from *Social Indicators*. Stats NZ website [23] (vertical axis title added).



2.4 Licensing and inspection

All Early Childhood Education Services are licensed by the Ministry of Education, under the Education Act 1990. For centre-based services, the licensing process involves a health report from a Public Health Service. The health report covers compliance with the health-related clauses of the Education (Early Childhood Services) Regulations 2008, and of the *Licensing Criteria for Early Childhood Education & Care Services 2008* [24], including minimum space and hygiene facilities, and some safety requirements. While the Ministry of Education only requires a health report before a centre opens, some Public Health Services encourage communication with the Public Health Service early in the planning stage, for example Te Toi Ora Public Health in the Bay of Plenty [25]. This process is dependent on the cooperation of the centre developer. Other Public Health Services, for example Wellington Regional Public Health, may arrange a follow-up visit a year after a centre opens [26].

A new service receives a probationary licence for one year, following which they receive a full licence if the Ministry of Education is satisfied that they meet licensing requirements. A service can be placed back on a provisional licence if the Ministry of Education deems that they are not meeting licence requirements, and may cancel the licence if the conditions of the probationary licence are not met (Education (Early Childhood Services) Regulations 2008). If the Ministry of Education is concerned about health or safety-related requirements, it may request a health report from a Public Health Service. Alternatively, a Public Health Service may alert the Ministry of Education if it has concerns, but at this point in time there is no Ministry of Education contract for Public Health Services to regularly inspect or assess ECE Services.

Once a centre is open, either the centre or its parent organisation will be subject to reviews by the Education Review Office (ERO). These reviews occur every two to four years, or as arranged by the Ministry of Education (this is the case if there is a high level of concern about children's health and safety) [27].

2.5 Physical standards

2.5.1 Minimum space per child in New Zealand day care

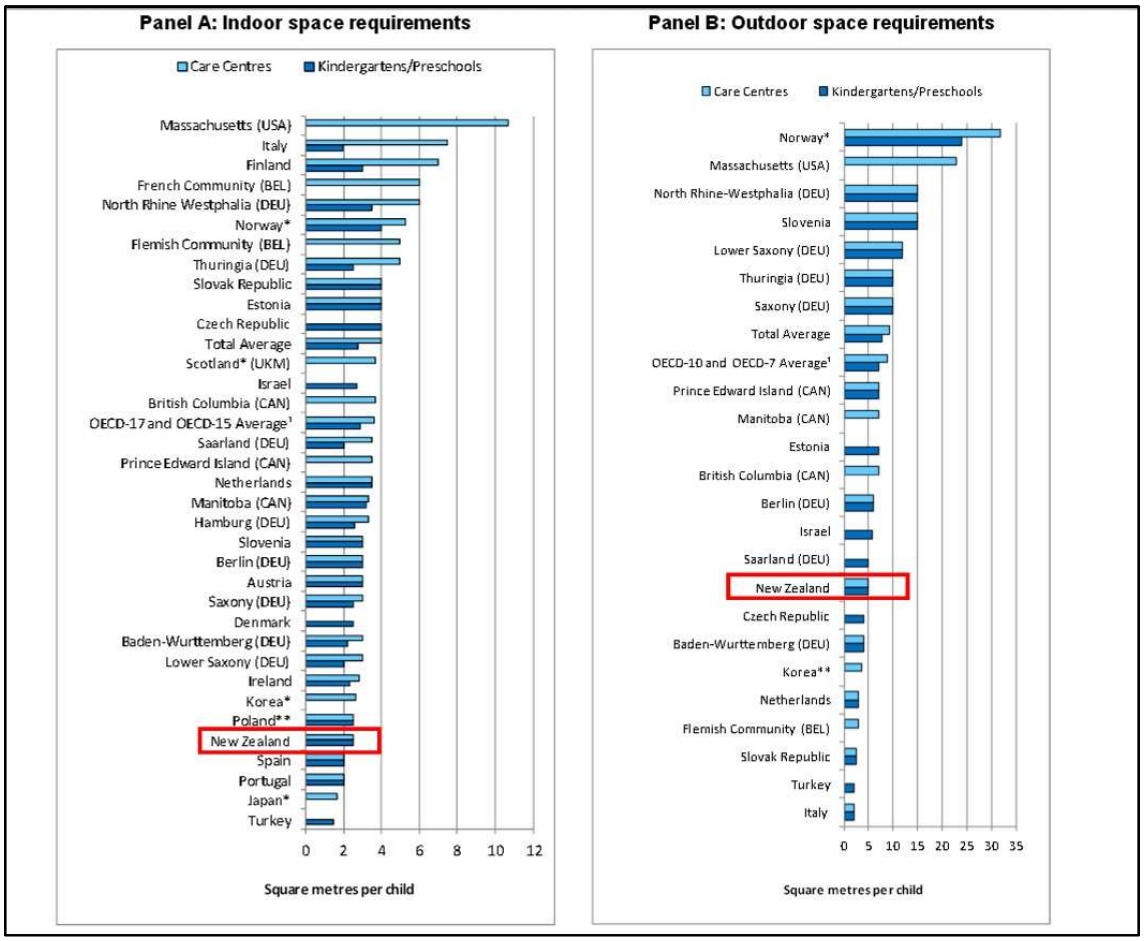
Figure 7 indicates that the minimum allocations of indoor and outdoor space per child in New Zealand early childhood centres are low compared with the minimum standards of comparable nations.

The New Zealand minimum space per child in early childhood centres is 5.0m^2 per child outdoors, and 2.5m^2 per child indoors (Education (Early Childhood Services) Regulations 2008). The comparison in Figure 7 from OECD.org is based on data from the OECD Network's *Survey for the Quality Toolbox and ECEC Portal* [28] and on the OECD's desk-based research. (Note: There can be difficulties in comparing standards between countries, as the descriptions of space calculation vary, and different requirements may be applied to different age groups. Age grouping are inconsistent across jurisdictions.)

The 2008 Education (Early Childhood Education Services) Regulations 2008 refer to "indoor space" and require it to be calculated as follows:

> Indoor space for all services is calculated by excluding the space occupied by all fittings, fixed equipment, and stored goods, and excludes passage-ways, toilet facilities, staff rooms, specific sleeping areas for children under two years of age, and other areas not available for play.

Figure 7: OECD comparison of regulated minimum space per child in ECE and care centres, reproduced from OECD.org [28].

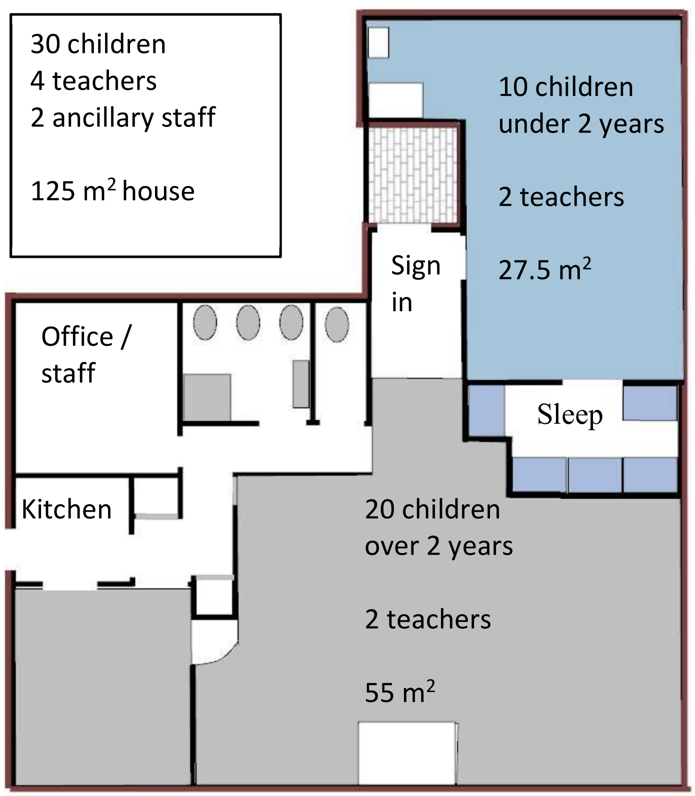


Early Childhood Education Services, including full-day childcare services, may be set up in almost any kind of building, ranging from converted houses to office space to purpose-built buildings. A comparison with a typical converted 3–4 bedroom house of 125m^2 provides a picture of crowding under current legislation. In the scenario illustrated below from a 1960

New Zealand house (Figure 8), floor space has been calculated at 2.5m^2 per child, and requirements for sleep space and toileting facilities have been met. Since 2008, separate sleeping space has not been required for children over two years old. Space for "fixtures and fittings" is allocated at 10% of available activity space, following current Ministry of Education practice for licensing.

This is a typical and realistic house conversion for childcare for children from birth to five years old. The teacher:child ratios applied are 1:5 for children under two years old, and 1:10 for children over two years old.

Figure 8: Childcare space in a converted residential home



There is an additional crowding issue that can occur where the separation of spaces prevents children moving from one space to another, for example in buildings with connecting corridors or stairways off-limits to children, or where separate buildings are part of one licence. Consider, for example, a licence for 40 children in total, including 15 children less than two years old housed in a separate building from the children over two years old. If the centre has fewer children enrolled in the under twos area than their licence allows, they could enrol more children aged over two. The result could be, for example, 30 children occupying the 25-child space for children over two years. The space per child allocation would be illegal, but it would not be detected by the Ministry of Education remote monitoring of daily attendance, as the centre would be within total licensed numbers.

2.5.2 Noise and sociological consequences of crowding, and secondary effects of stress

The potential for infection spread in crowded conditions is a driver for this thesis, but other normal consequences of crowding such as noise and stress also apply in childcare [29, 30]. Early childhood centres are active environments with children either at a pre-social awareness stage, as for infants, or at early stages of socialisation. The Lombard Effect, that describes the positive feedback loop of conversation volume in a constrained space, applies in childcare [29, 30]. Children and teachers need to raise their voices to overcome background noise, which in turn increases volume. Crying children, especially crying babies, will exacerbate the situation. ECE and care environments include children at early stages of social development, as well as children with developmental and behavioural issues. There may be children present with conditions such as Asperger's Syndrome, for whom a crowded and noisy environment may be unbearably stressful [31]. Stress also reduces immune response [32], increasing the likelihood of illness in children and teachers.

2.5.3 Minimum temperatures in New Zealand day care

The results of an English language Google search for relevant statutes and/or recommendations for minimum temperatures in ECE and care are shown in Table 3. The search found just one recommendation or requirement below 18ºC, other than the New Zealand legal minimum of 16ºC, which was Minnesota State, US at 16.7ºC. The recommendations of the World Health Organisation (WHO), 25 US states, three Canadian States, Ireland and the Isle of Man are all 18ºC or higher. (In Table 3 some results are shown as 'not found' as there may be relevant guidelines or recommendations not found in the web search.)

Table 3: Requirements or recommendations for day care minimum indoor temperatures

Jurisdictions or recommendations	Minimum temperatures
10 US states[33-42]	20
3 Canadian states[43-45]	20
National Resource Center for Health and Safety in Child Care and Early Education (United States)[46]	20
2 US states[47, 48]	19.4
12 US states [49-60]	18.3
Illinois[36]	18.3 / 20
Ireland[61]	18
Isle of Man[62]	18
World Health Organisation - home / workplace[63]	18
New Zealand 1990-98[64]	18
Minnesota[65]	16.7
New Zealand 1998-current[66, 67]	**16**
2 US states[68, 69]	Not found
4 Canadian States[70-73]	Not found
UK - national standards[74]	None
Australia[75]	None

An earlier version of Table 3 was presented in June 2018 in a videoed seminar at the University of Otago, Wellington [76]. The presentation was followed by news media attention, including national radio and television. Radio New Zealand asked the Ministry of Education why we used a minimum temperature of 16ºC, and was given this statement: “The minimum temperature of 16°C reflected the fact that children were allowed to move freely in and outdoors so in many cases doors might remain open” [77].

New Zealand has a temperate oceanic climate [78] that does not generally present the temperature extremes experienced in continental climates, so the climate itself would not justify an inability to heat the buildings to 18ºC or more. While the need for outdoor access presents challenges for heating systems, options such as suspended infrared panels or other radiant systems could help to solve this problem. Radiant heaters are typically specified for large areas such as sports halls, industrial buildings, warehouses, churches and atria [79]. BRANZ recommends infrared heating for buildings with a high volume of air flow from outside, or high heat loss, as the infrared radiation will heat the thermal mass of the room [80]. High-mounted heat pumps must overcome the tendency for warm air to rise, presenting a challenge for heating at child level. Unfortunately building design can be poor, even for ‘purpose-built’ childcare centres, as illustrated in Figure 9. A heat pump in the location shown will be subject to potential immediate heat loss when the door is open.

Figure 9: Heat pump located next to the door to the outside area in a childcare centre

The door needed to be open often to allow children access to the outdoors.

2.5.4 Regulation changes – from emphasis on health and safety to emphasis on qualifications – for the loss of health and safety?

There have been a number of significant changes in the jurisdiction of early childhood education and care in New Zealand in the past six decades. Prior to 1990, the sector was divided between Free Kindergartens and Playcentres, under the jurisdiction of the Department of Education, and ‘childcare centres’, under the jurisdiction of the Department of Social Welfare. Brenda Bushouse described the formation of The New Zealand Childcare Association (NZCA) in 1963, as a way to organise the disparate providers of day care after the first regulations for childcare centres emerged in 1960. Bushouse explained that, “A key problem identified by the NZCA was the lack of training for childcare centre workers. The childcare regulations focused on health and safety, and it was therefore possible to meet the licensing standards while providing low quality care” [81]. The 1960 Child Care Centre Regulations divided centres into two classes: Class A, requiring at least one person with a teaching or nursing certificate, and Class B, for which no qualifications were required.

Declining physical standards

The emphasis on health and safety rather than qualifications and pedagogy noted by Bushouse was to see a reversal from 1985 onwards. By 1988 qualification requirements had increased to a minimum 50% with an early childhood education qualification for teacher-led centres, and 1996 saw the release of the *Te Whāriki* early childhood education curriculum guidelines, but most physical measures, including teacher:child ratios, entered an overall downward trend.

Some of the changes were to numerical standards, for example the change in indoor space between 1960 and 1985. In 1960 indoor space per child was 25 square feet (2.32m^2) for children over two, and 40 square feet (3.72m^2) for children under two. At that time relatively few children under the age of two were in all-day care, and outdoor space was not considered for this age group. Outdoor space was allocated for children over two at 75 square feet (6.97m^2) per child. The Child Care Centre Regulations 1985 changed the indoor space to 2.5m^2 per child for all age groups. Outdoor space was reduced to 5m^2 per child, but gave the benefit of allocating outdoor space to children under two. In 2008 the indoor space was reduced by a wording change (inclusion of 'furniture' in floor space), with the result that floor space would now include space occupied by tables, chairs, couches and other movable items. (Education (Early Childhood Centres) Regulations 1990; Education (Early Childhood Services) Regulations 1998)). The effect was to reduce activity space by approximately 10%, equivalent to the 1960 over-twos' indoor standard. It made the wording equivalent to Australian federal law, but in that requirement the space allocation is 3.25m^2 (Children (Education and Care Services) National Law (NSW) No. 104a, 2017). This space allocation does not include adults, so the per-person rate will be reduced by another 10–25% (between 1:4 and 1:10 ratio of teachers to children), producing an actual allocation of between 1.7m^2 and 2.2m^2 per person. By contrast, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommendation for childcare is 100m^2 for 25 people, or 4m^2 per person (American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE), 2016).

The minimum temperature in 1960 was 60^oF (15.5^oC), which was reduced to 15^oC in 1985. This was increased to 18^oC in 1990, but then reduced to 16^oC in 1998. Other changes included a reduction in handbasins from 1:10 persons down to 1:15 persons in 1998, and the removal of separate sleep spaces for children over two years old in 2008.

An error in the Education (Early Childhood Services) Regulations 1998 suggests that the 1998 regulation changes in particular were made with very little consultation between the Ministries of Education and Health. The 1998 regulations allocated the responsibility for health reports (from the Public Health Units to the Ministry of Education) to the 'Health Funding Authority' (HFA). The HFA was a budgeting and purchasing office of the Ministry of Health that had no operational role in health, and did not provide health reports.

2.6 Conflicting pressures and ideologies

The 2008 regulation change to minimum indoor space was also unusual from a legislative consultation perspective, in that the reduction in space had not been notified in an otherwise substantial regulation review consultation process, and was not known to Wellington Regional Public Health at the time (from personal experience coordinating the Regional Public Health ECE programme 2005–2009, and as indicated in the 2006 Wellington Regional Public Health submission on the Licensing Criteria (Appendix 1). The Wellington Regional Public Health Service was already concerned about the inadequacy of minimum space, and had engaged with the Ministry of Education by way of discussion and a submission on the proposed regulation changes. As it would reduce space for both children and teachers, it is hard to imagine a rationale for this particular change other than commercial pressure. Commercial interest is, however, just one of many potentially conflicting pressures influencing policy, regulations and quality in the ECE and care sector.

Ideologies have also affected early education and care in New Zealand. The 2011 report, *An Agenda for Amazing Children: Final Report of the ECE Taskforce,* had ten guiding 'principles'. Of these, half were related to economics and centre-right political ideology, rather than care and education, including "fiscal restraint" and "economic growth," and advocating for early return to work by parents [82]. The ten principles were:

1. Respect fiscal constraint
2. Promote economic growth
3. Use government funds efficiently
4. Fairness: Encourage cultural diversity
5. Fairness: Ensure access for all to high-quality early childhood education services
6. Encourage parental connections to the paid workforce

7. Create a predictable environment for service providers
8. Pursue administrative simplicity and low compliance costs
9. Encourage sector collaboration
10. Promote innovation across the sector

The report recommended

> ...increased productivity by greater support for working parents. That means… support from the Ministry of Social Development and the Ministry of Education should be combined into a single, transparent, easy-to-understand system that offers incentives and support for parents to return to paid work. [82].

The same report promoted longer hours for children in day care, because,

> Differences in these numbers of hours have significant labour market implications. Service types with a smaller number of hours per child – whether this is because they are closed for holidays or because children attend for only a few hours per week – are less likely to support parents engaged in paid work… It is not a big jump to link this to the extent to which those services empower parents to work. Broadly, they offer better value for money, provided, of course, that they are of high quality.

The New Zealand early education and care environment has also involved pressures which, while intended to be in children's interests, can produce harmful results if out of balance. An example of this is the Ministry of Education target of 98% participation in quality ECE before a child attends school [83]. The implementation has seen ECE centres encouraged to have maximum occupancy (personal communication with a childcare centre manager in the Wellington region, 2016), which means minimum space per child, without rigorous consideration of whether maximum occupancy is consistent with quality. This approach contrasts with previous quality approaches in the Ministry of Education. The 2007 Ministry of Education 'Design and Build Project' developed generic modular plans for ECE centres, intended to be based on quality provision rather than minimum standards. Reflecting this approach, the plans featured better than 3.0m^2 per child, rather than the minimum 2.5m^2 per child (see Appendix 2).

Concerns about the 'participation focus' were expressed by Sue Cherrington, Associate Dean (Academic) of the Faculty of Education at Victoria University of Wellington, in 2017. "While increasing participation rates, particularly for Māori and Pasifika children and for children from disadvantaged backgrounds, was a core policy initiative of your predecessor [the previous Minister of Education], the same attention has not been paid to making sure that children are participating in high quality ECE services. The time has come, Minister, to shift the focus from participation, or quantity, to a focus on quality" [84].

2.7 Childcare as business

A major change in the early education and care sector has been the rise of childcare as a business and as an investment, rather than an activity centred on care or education. Colliers International Investment Sales Broker Peter Kermode is quoted on a Colliers website (Figure 10) as saying,

"Childcare centres offer strong fundamentals at a relatively affordable price point, making them attractive to smaller investors like family trusts… Childcare centres are higher yielding than residential investments, and require a lot less management. Typically, the tenant pays all the outgoings." Kermode writes that "...ownership models are changing rapidly," and explains that, "...while there continues to be a market for these smaller centres, the market has shifted towards much larger operators, running multiple centres licensed for far more children."

Figure 10: Childcare as business [85]

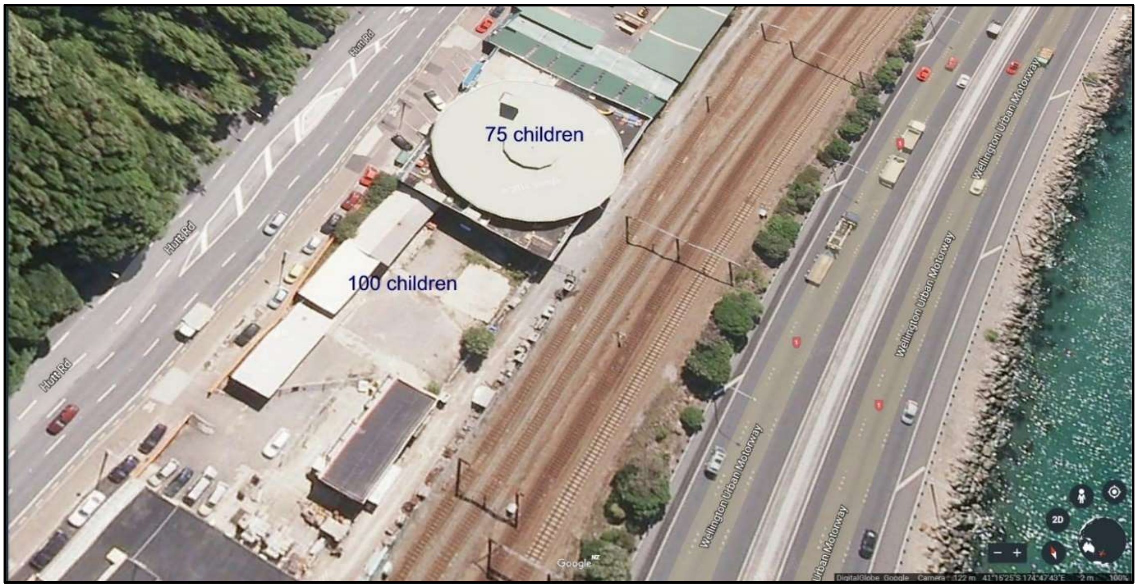
Examples of larger operators in the article include Evolve Education Group and Best Start Educare. Evolve Group is a publicly listed company, as was Best Start Educare prior to 2015, under the name Kidicorp. Kermode states that, “These larger operators are developing purpose-built early childhood centres that typically accommodate between 80 to 120 children. Some are even large enough to accommodate 200 children... [The driving factor] is ‘economies of scale’” [85].

Kermode said, “Children’s needs won’t change much over time, while demand for childcare is likely to remain strong, as Auckland house prices necessitate dual income families.” The commercial drivers of investor expectations and high house prices may be disadvantageous to children, especially if the investors do not have a direct interest in the outcomes for children. The commercial motivation may see a preference for minimum standards, including minimum spaces, temperatures and teacher:child ratios. Parents, and consequently their children, can become a captive market, needing to use minimum-standard childcare out of economic necessity.

2.8 Air quality and ECE centre location

Air quality in New Zealand preschools has been under-researched, although there are currently three relevant postgraduate research projects under way – one based at Otago University, one based at Massey University, and one at the University of Auckland. Very young children are particularly at risk from exposure to pollutants, having a higher metabolic rate and oxygen consumption than adults, and consequently greater intake of air per unit body weight [86, 87]. In addition to these factors, lung growth and development, and incomplete metabolic systems, can lead to higher exposure to higher doses of pollutants reaching the lungs. Aspects of body detoxification systems may increase the effects of this exposure [88].

Figure 11: Location of childcare centres in a high-traffic commercial location



Childcare centres may be located along busy arterial routes (see Figure 11), as these locations are convenient for parents and provide passive advertising, but these locations also expose the children to high levels of traffic pollution and noise. In the example in Figure 11 only the site of the 100-child centre is shown, as the building (which is complete and occupied) had not been built at the time when the Google Earth photograph (last accessed December 2018) was taken. The street frontage of the circular building can be seen in the lower photograph.

2.9 Possible blind spots in epidemiology and health policy

A blind spot in public health?

The early childhood education and care sector has suffered for many years from a degree of invisibility in public policy and research, when considered outside of the ECE sector itself. This blind spot has been evident in Ministry of Health documents, and can be seen in research into infections that are likely to be related to ECE attendance.

The Ministry of Health document *An Integrated Approach to Infectious Disease: Priorities for Action 2002–2006* contained only three very minor references to early childhood centres. Early childhood centres were not mentioned at all in relation to respiratory infections, and not mentioned under ‘the environment and infectious disease’. They were given a brief mention as ‘crèches’, (see Glossary) in a table under “Health and disability care institutions” in relation to handwashing [89].

The 2004 Ministry of Health *Child and Youth Health Toolkit* stated that “…the settings in which children live, play and work (i.e. homes, schools, communities and society) have a profound impact on health,” but nowhere in the 100-page document were early childhood centres recognised as having an impact on health. The document described “life-cycle transitions,” the largest being “birth and the rapid growth of infancy, followed by toddlerhood and preschool years (home), middle childhood (primary school), adolescence (secondary education)…” [90]. Despite societal changes that saw many children spending more hours per day in childcare than children spend at school, the potentially stressful transition from home to day care, with its associated increase in infection rates, was not recognised.

More recently, the *New Zealand Health Strategy: Roadmap of Actions 2016* contained just one reference to ECE and care environments: “Enhance collaboration between early childhood services and health services for pre-schoolers, to improve early childhood education attendance and better address unmet health and development needs” [91]. This statement reflects a common perception that attendance automatically provides a health advantage, without necessarily considering the quality of the environment.

The Ministry of Health has never had a single full-time national-level position for early childhood education and care-related health, and lacks a coordinated national ECE programme, other than compliance inspections for newly established centres.

Epidemiology

The potential for early care and education environments to play a significant role in disease transmission tends to be overlooked in New Zealand epidemiological research, and in disease prevention. For enteric infections, this may be due to a historic categorisation of these infections as ‘food or waterborne diseases’. Many of the infections likely to be transmitted by food or water are also spread by the faecal-oral route, and for human viruses and the protozoan infections Giardia and Cryptosporidium, food and water are not origins of infection but two out of a number of means of dissemination.

An example of the emphasis on food and water can be seen in the Giardia section of the New Zealand *Communicable Disease Control Manual* [92], which describes the mode of transmission as follows:

> Transmission occurs from ingestion of faecally contaminated food or drinking-water, swallowing recreational water (for example, swimming and wading pools, streams and lakes), exposure to faecally contaminated environmental surfaces, and person to person by the faecal-oral route.

Giardia does not multiply in water or food, but the assumption of water as the primary transmission mechanism may be affecting the resourcing of Giardia prevention and the interpretation of related research. In New Zealand the highest notification rate is for children aged one to four years, 1.8 times the next highest rate, which is for the 30–39 year old age group. The second- and third-highest rates are for adults in the groups most likely to have children in the one to four year old group (20–39 years) [93]. The peak incidence of giardiasis and cryptosporidiosis in very young children has been viewed as an artefact of the notification process, as has the secondary peak for giardiasis in women in their early parenting years (from personal experience, Wellington Regional Public Health Communicable Disease Team, 1996–1999). This was based on the availability in New Zealand of free doctor visits for children, and the likelihood that mothers would also visit the GP and have a confirmed (therefore notifiable) diagnosis. Against this assumption, both giardiasis and cryptosporidiosis have been observed to be endemic in day-care settings in the United States since the early 1980s [94, 95].

In the thesis *Epidemiology of Enteric Diseases* [96], hospitalisations for both giardiasis and cryptosporidiosis were found to be higher for females than males, suggesting that the reported increased rates in children and women may reflect real differences in infection rates (unless women have more severe morbidity when infected). For giardiasis, Lal found that the majority of results in the study alluded to infection sources that were predominantly human. Poor, intermediate or unknown drinking-water quality was found to be slightly protective for giardiasis. This is unlikely to be a real indication of the risks of high-quality water supply compared with low-quality, but it does suggest that water is not the greatest risk factor. High rates of Giardia infection are reported in urban areas, including Wellington, and Wellington has a very high-quality (A1a1 grade) water supply [97], as do Auckland and Nelson. Despite these indicators and the steep increase in childcare use in New Zealand since the 1980s, discussion of socio-economic and population behaviour factors in Lal's thesis did not include the role of early childhood centres.

In an earlier study by Auckland Regional Public Health (ARPH) [98], risk factors for early childhood giardiasis included:

- The wearing of nappies (diapers), identified as a significant risk factor in early childhood giardiasis[a] OR 3.0 (1.01–8.9)
- Early childhood centre attendance, OR 2.3 (1.01–5.0)
- Staying away from home in NZ, OR 2.5 (1.2–5.2)
- Families in which there are two or more children in nappies OR 6.5 (1.4–21.9, depending on model)

[a] This is likely to relate to the risk of a child not being toilet-trained, and potential contamination from nappies, rather than the act of wearing nappies.

- Attendance at an early childhood centre and eating a meal at the centre 2.3 (1.01–5.0), as opposed to not eating a meal (OR 0.53)
- Contact with other giardiasis cases OR 11.3 (6–35).
- Drinking water away from home (OR 1.9–12.0).

The ARPH study considered exposure to water sources other than the Auckland Metropolitan Water Supply. Only river water showed a significant result at OR 10.9 (1.9–55.8), and this was from only five cases compared with one control. Bottled-water consumption showed a non-significant positive association at OR 2.4 (0.74–8.1). Swimming was also a risk factor, but only six cases swam in a river, compared with 38 swimming in swimming pools or the sea. River swimming may involve use of public toilet facilities in recreational areas (increasingly equipped with public-use nappy change facilities). The sea is not a likely Giardia infection source, and while swimming pools certainly can be, the mechanism is a likely to be effectively person to person via the pool itself and wet surfaces, rather than from the water source for the pool. Despite the preponderance of hygiene-related risk factors, and the weakness of water-supply sources as significant risk factor, the authors concluded that:

> The quality of water consumed by these children is important in controlling the transmission of this disease. Recreational or environmental exposure to this parasite remains a real public health challenge. Travelling in general should be regarded as a risk, while effective toilet training and increased hygiene may reduce the transmission of disease. This study also suggests areas of further research, especially on exposure to water.

Giardia has generated outbreaks in New Zealand ECE centres, but enteric viruses such as rotavirus and norovirus are likely to be the cause of many more outbreaks. There have been difficulties in capturing the data, however, due to inadequate resourcing of Public Health Units, and because of the requirements for notification of 'acute gastroenteritis' (from experience with Wellington Regional Public Health, 1992–2009, and discussion with Public Health staff around New Zealand in 2016). The *Communicable Disease Control Manual* [92] states that:

> ...not every case of acute gastroenteritis is necessarily notifiable, only those where there is a suspected common source or from a person in a high-risk category (for example, a food handler, an early childhood service worker) or single cases of chemical, bacterial or toxic food

poisoning, such as botulism, toxic shellfish poisoning (any type) and disease caused by verotoxin – or Shiga toxin-producing Escherichia coli (VTEC/STEC).

In this explanation 'early childhood service workers' are considered a risk, but not the children or the general early education and care centre environment. There is little incentive for Public Health Units to properly investigate and report gastroenteritis outbreaks in ECE settings. An acute gastrointestinal illness study conducted during 2005–2007 estimated that only 0.4% of community cases result in a notification.

2.10 In the news – concerns about quality, temperatures and space

In recent years, New Zealand news media and ECE websites have published a number of articles expressing serious concerns about quality of care in ECE centres. The article below (Figure 12) referred to research by Child Forum, surveying 600 early childhood teachers. A quarter of the respondents said that they would not want their own child attending the centre they worked at because of quality issues. The survey quoted a teacher as saying, "It is like factory farming for children; I have said to my friends, 'Do not wait-list your child here…'"

Figure 12: "It is like factory farming for children" [99]

RNZ Home News Radio Podcasts & Series Topics Pacific

New Zealand World Politics Pacific Te Ao Māori Sport Business Country Comment

NEW ZEALAND / EDUCATION

'It is like factory farming for children'

5:07 pm on 7 October 2015

Share this

John Gerritsen, Education Correspondent - john.gerritsen@radionz.co.nz

A survey of early childhood teachers has raised allegations of under-staffing and factory farming for children.

A quarter of the 600 respondents to the survey by non-profit group Child Forum said they would not send their own children to their workplace because it is not good enough.

In an article on the Child Forum website (Figure 13), concerns were expressed about very cold temperatures in childcare. The article reported a teacher as saying, “We are told, ‘I don’t want another high power bill,’ or given reasons such as, ‘It’s 9 a.m. and there are enough bodies in the room’ (despite the room sitting at around 10 degrees and the staff wearing puffer jackets and scarves inside!)”[100].

Figure 13: Extract from Child Forum Website – “Freezing Cold Early Childhood Centre” [100]


CHILD FORUM

ChildForum Early Childhood Education Nationwide Network

Promoting quality, valuing knowledge, advancing thinking and working together for the benefit of children, services and the sector

FREEZING COLD EARLY CHILDHOOD CENTRE – SAVING CENTRE POWER BILL COMES BEFORE CHILDREN

PUBLISHED: TUESDAY, 29 AUGUST 2017 09:41
HITS: 3396

1 Comment

By a qualified certificated New Zealand ECE teacher (name withheld)

Opinion article

As a teacher I never thought I would find myself having to fight for **children's right** to stay warm in their centre in winter.

When I became an **early childhood education** teacher I thought of all the fun learning experiences I could provide for tamariki. But time for this starts to take a back seat when it's too cold for children and management is not worried about the centre not meeting regulations for room temperature every day.

Nine times out of 10 when we have the heating on management walk in and turn the heat pump off.

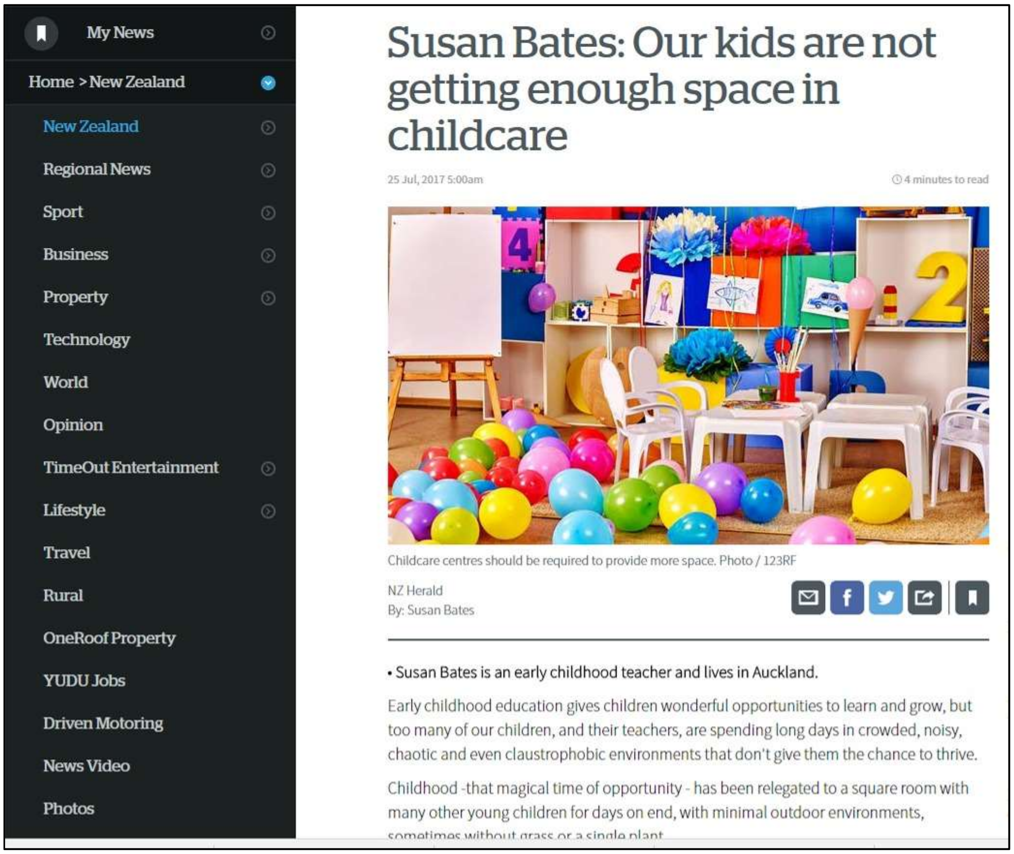
We are told: "*I don't want another high power bill*" or given reasons such as "*its 9 am and there are enough bodies in the room*" (despite the room sitting at around 10 degrees and the staff wearing puffer jackets and scarves inside!).

Another early childhood relieving teacher and researcher, Susan Bates, publishing in the *New Zealand Herald*, expressed concern about crowding and minimum space standards (see Figure 14) [101]. Bates stated that:

> In theory, services are highly regulated, and many advertise qualified staff, but in practice, our regulations fall far short of international best practice. I have spent time in almost 40 centres and found very few gave children the chance to run around or have vigorous exercise that healthy young bodies and minds need at this age, or indeed any age. Many teachers don’t feel their children have enough room to move. What is the evidence the Ministry of Education is using to calculate space in early childhood? Why were regulations changed in 2008 to reduce the space? Why doesn’t the ministry consider overseas best practice? Why does the Ministry

of Health provide no guidelines regarding ideal space and group sizes for young children? Where is the measurement for safe noise levels and ventilation?

Figure 14: "Our kids are not getting enough space in childcare" [101]


My News
Home > New Zealand
New Zealand
Regional News
Sport
Business
Property
Technology
World
Opinion
TimeOut Entertainment
Lifestyle
Travel
Rural
OneRoof Property
YUDU Jobs
Driven Motoring
News Video
Photos

Susan Bates: Our kids are not getting enough space in childcare

25 Jul, 2017 5:00am

4 minutes to read

Childcare centres should be required to provide more space. Photo / 123RF

NZ Herald
By: Susan Bates

• Susan Bates is an early childhood teacher and lives in Auckland.

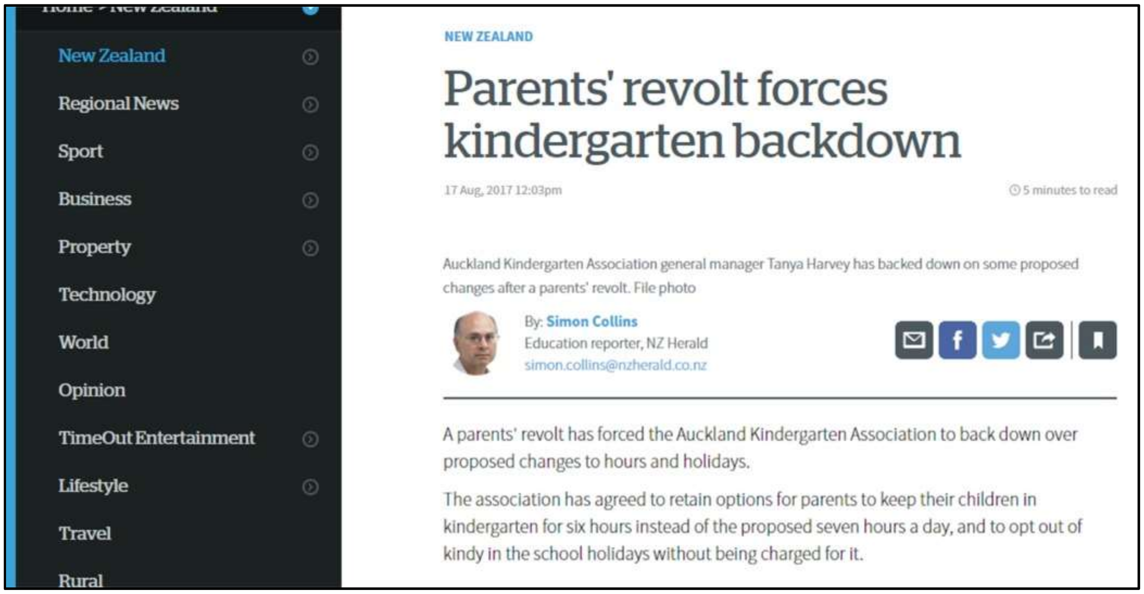
Early childhood education gives children wonderful opportunities to learn and grow, but too many of our children, and their teachers, are spending long days in crowded, noisy, chaotic and even claustrophobic environments that don't give them the chance to thrive.

Childhood -that magical time of opportunity - has been relegated to a square room with many other young children for days on end, with minimal outdoor environments,

There have also been concerns about longer hours and parents being forced to pay for school holiday hours when their children are attending, expressed in the following article about Auckland Kindergarten Association (see Figure 15).

This argues against the idea that longer hours are *only* in place to meet parent demand, rather than being commercially driven.

Figure 15: "Parents' revolt forces kindergarten backdown" [102]



New Zealand
Regional News
Sport
Business
Property
Technology
World
Opinion
TimeOut Entertainment
Lifestyle
Travel
Rural

NEW ZEALAND

Parents' revolt forces kindergarten backdown

17 Aug, 2017 12:03pm

5 minutes to read

Auckland Kindergarten Association general manager Tanya Harvey has backed down on some proposed changes after a parents' revolt. File photo

By: Simon Collins
Education reporter, NZ Herald
simon.collins@nzherald.co.nz

A parents' revolt has forced the Auckland Kindergarten Association to back down over proposed changes to hours and holidays.

The association has agreed to retain options for parents to keep their children in kindergarten for six hours instead of the proposed seven hours a day, and to opt out of kindy in the school holidays without being charged for it.

2.11 Summary

The Ministry of Education and others have stated that we have "among the best standards for early childhood education in the world" [103], but there is a lack of research into the physical conditions in early education and care. There is certainly cause for concern over New Zealand's physical standards of space and minimum temperature. Prior to this study and concurrent research in Auckland, we have not had a measure of the operating temperatures in New Zealand's early education and care centres. We have not had a survey of operating space per child, or a study of symptomatic infection rates in children attending the institutions. This thesis examines three aspects of environments and child health in New Zealand day care: crowding, temperatures and humidity, and infection rates. This research sits in the wider context of policy-making and our attitudes as a nation to the first years of human life.

3 Literature Review

3.1 Overview and scope

Chapter 2 described two New Zealand ECE environmental standards that are low in comparison to other OECD countries. These are the minimum temperature standard of 16°C, and the minimum indoor space standard of $2.5m^2$ per child. The initial question under consideration was, 'Do these environmental conditions influence infection rates in early childhood care and education settings'? The literature review explores the relationship between these settings and infectious disease rates, with particular emphasis on crowding and indoor temperatures. The review identifies previous studies that were specific to education and care settings, and that had included measures of the physical environment and health outcomes. It is also a review of wider topics that can inform the research.

The review was based on the combinations of three categories of search terms: setting, environment, and outcome. The setting was the non-parental group care and education of preschool children. The environment, for this purpose, included conditions such as crowding and temperatures, as well as other environmental factors such as microbiological loading and survival, and air quality. The primary outcome of interest was communicable disease infections. Information was also considered for two non-infectious conditions influenced by the physical environment and related to infections when found in the search – atopy and asthma, although these conditions were not included in search terms.

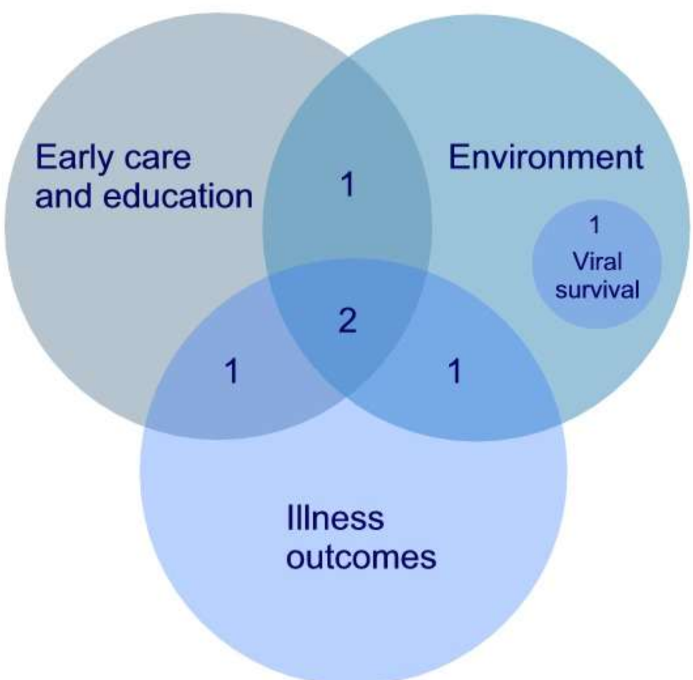
The literature review had two parts:

1. Literature that described relationships between two of the three components in Figure 16, to provide information on illness rates in the setting. For example, do early care and education environments present a risk of increased illness rates? What are the effects of temperature on human health?

   One additional search was included with just one component: information on viral survival in the environment.

2. Studies and associated publications that connected all three study components. These studies were reviewed in detail as examples of previous research with a similar scope. Crowding, temperature and humidity were of particular interest.

Figure 16: Literature search components



Part 1 (Sections 3.2, 3.3): literature related to two out of three components, plus environmental viral survival

Part 2 (Section 3.4): studies involving all three components

The review used a three-stage grid search (title selection, abstract selection, article selection), supplemented by citation links. Each Scopus search combined terms for the setting, environmental conditions and infection outcomes, as shown below:

Scopus was chosen because it searches a number of other relevant databases, including a claimed 100% coverage of MEDLINE, EMBASE and Compendex. The number of initial results combined with limitation on time and resources made a grid search with more than one search engine impractical.

To reduce the number of searches, each search used all childcare or early childhood education terms, and used wildcards and groupings of other search terms. This reduced a total of 5049 combinations to 198 searches. The ‘viral survival’ search without ECE setting terms added 117 results, of which 13 titles were selected.

3.1.1 Search terms

Using the search terms in Table 4 the title search produced 13,478 titles. After removal of duplicates, 600 titles were selected at abstract level, from which 147 titles were selected for detailed reading in the literature review. Another 94 titles were chosen from citation links or other sources (see Section 3.1.3 for the rationale for inclusion).

Table 4: Search term combinations

Setting	Environment	Infections / outcomes
childcare	temperature*	infection* or ill* or sick*
"child care"	"minimum temperature"	virus or viral
daycare	heat*	bacterial
"day care"	humid*	gastrointestinal
kindergarten	damp*	enteric
preschool	ventilation	respiratory
pre-school	"space per person" or "area per person"	"ear infection*" or "otitis media" or AOM or OME
creche	"space per child" or "area per child"	cold*
nursery	CO2	*influenza
early childhood centre	"air quality"	"respiratory syncytial virus" or RSV
early childhood education	environment	rhinovir*
		adenovir*
		rotavir*
		norovir*
		campylobacter*
		giardia* or cryptosporidi*
		clostridium difficile
		"work time" or absence*

3.1.2 Subject and date filters

An age-group-based filter was applied to exclude the Scopus subject areas ‘adolescent’, ‘young adult’, ‘middle age’, ‘middle aged’, ‘aged 80 and over’ and ‘non-human’. A test was conducted using these terms plus temperature* AND infection* OR ill* OR sick*. These terms returned no titles of relevance to the study in the first 200 results, suggesting little cross-over between studies concerning these age groups and studies concerning preschool children.

Where searches returned large numbers of results, other Scopus keyword exclusions were applied, if they were clearly not going to affect relevant titles and would reduce the search volume, for example ‘veterinary’. Other terms drew in many titles from irrelevant topics. The first search for ventilation* AND infection* OR ill* OR sick* (with all setting terms) returned 4123 results but most of these concerned ventilation system engineering or ‘ventilation’ as a specific medical treatment. Results were reduced by application of age group and date filters to 127 titles.

Larger searches were generally limited to results from 1980–2017. Searches including the term ventilation* were further limited to the years 2000–2017, due to the number of articles not relevant to ECE or childcare.

3.1.3 Title inclusion

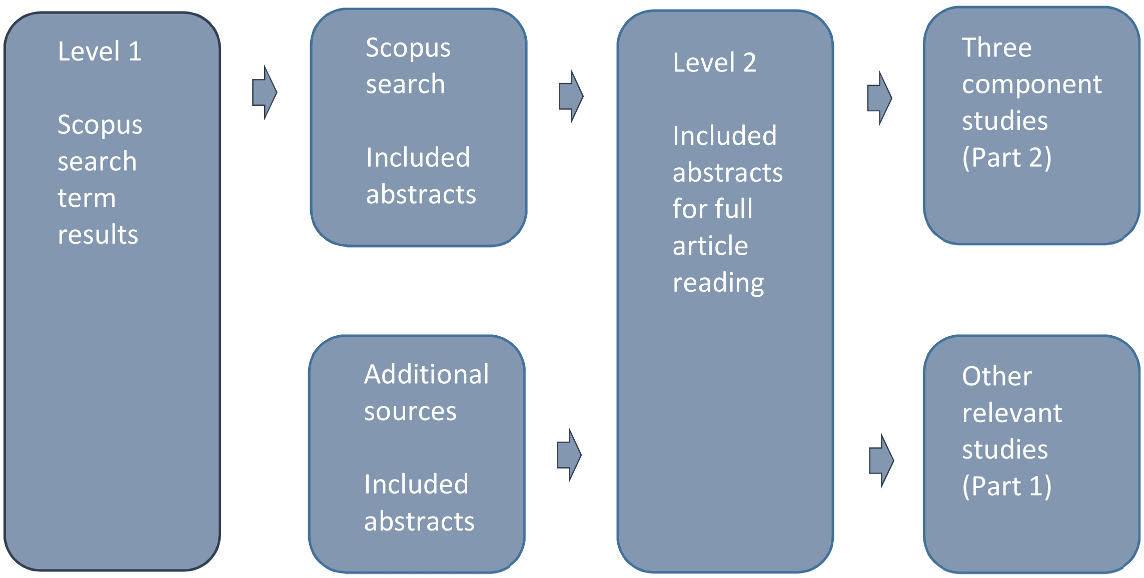
The search was not a strict systematic search, as it involved the exploration of potentially relevant information to build a bigger picture of early care and education-related illness and mechanisms of environmental infection spread, as well as financial and quality-of-life costs. All titles clearly related to setting terms were included in the first cut, but many others were included simply because they appeared to address a relevant issue, for example, *Otitis media and child development: Should we worry?* [104]. This wider view informs decisions as to the importance or otherwise of the study findings – why bother, does it matter? The assumption was made at the beginning of the search that there may be topics of unexpected relevance, for example, *The lock-up phenomenon of exhaled flow in a stable thermally-stratified indoor environment* [105]. This study described the reduction in effective air volume in a thermally stratified room and consequent movement of exhaled particles and organisms, similar to the likely conditions of a poorly ventilated childcare sleep room.

Titles found in the initial searches were scanned to exclude those that were unlikely to be relevant, with remaining titles then checked at abstract level before being included in the second level. Some additional titles were found by other processes, for example Elsevier email notification of articles of potential interest, and were included if relevant at abstract level.

Titles were removed in the second cut due to duplication or inapplicability to the ECE / childcare setting. Twenty titles were included for which only the abstract could be found. These were included because sufficient information was found in the abstract to warrant inclusion as findings, bearing in mind that these papers could not be assessed for quality.

The articles selected for inclusion at Level 2 were then sorted by match to search terms, so that search results for each search term could be considered independently, e.g. all articles related to Giardia infections. Not all articles included in the second level have been referenced in the review, as many were limited in relevance when compared to references from other literature already included.

Figure 17: Inclusion of titles and abstracts



3.2 Part One (two components) – association between childcare attendance and infection

The relationship between childcare attendance and increased infection rates in children has been documented since the mid-1940s, if not earlier. A study by Allen-Williams et al. [106] published in 1945 analysed records from 438 children attending 11 day nurseries in Oxford, England. The infection rate in the 'day nurseries' was very much greater than that in the infant-welfare centres. The authors commented that children at any age attending a 'day nursery' were more likely to contract infections than children cared for in their own homes. Pönkä et at al [107] stated that in Sweden, as long ago as in 1949, a study by Hesselvik had found that children in childcare centres had more illnesses than those cared for at home. In later Scandinavian studies, childcare centre children were found to have about twice as many infectious diseases as those cared for at home.

In a 1996 Oslo study by Nafstad et al.[108] of 3,853 children born in 1992, children in day care were almost twice as likely to have had a night-time cough, and 55% more likely to have had a stuffy or runny nose than children who stayed at home. Chronic ear infections and asthma were more common among children in day care, particularly among those who started childcare before two years of age.

In 2010–13 Dutch surveillance by Enserink et al., children attending childcare consulted a medical doctor approximately twice as often for infections as non-attendees during the same period and for the same age group [109].

Sangrador et al. [110] conducted a systematic review (updated to June 17, 2006 without date or language limits) with a meta-analysis of studies that included children exposed to childcare centres before three years of age, and with follow-up during the years of attendance or later. For children attending childcare, compared with those cared for at home, risk of upper respiratory infection increased by 88%; for otitis media by 58%; for otitis media with effusion by 143%; for lower respiratory infections by 110% (pneumonia 70%, bronchiolitis 80%, bronchitis 110%); and diarrhoea / acute gastroenteritis by 40%. By transforming the estimated risks into attributable proportions, they concluded that childcare attendance could be responsible for between 33% and 50% of the episodes of respiratory infections and gastroenteritis in the exposed population. Another review, by Nesti et al. [111] (Brazil, only abstract available in English) found that children cared for at childcare or in preschool education exhibit a two to three times greater risk of acquiring infections, which impacts both on individual health and on the dissemination of diseases through the community.

Increased risk for very young children

The greatest risks of excess morbidity from childcare attendance infection occur in the first or second years of life. Childcare attendance is associated with a considerable health burden to families from excess respiratory infections in children under two years of age. The differences between childcare centre and home-care groups are most marked in one-year-old children. [112]. One review concluded that infants and children under three years of age in 'day nursery' are more frequently affected by infections, especially in the upper but also in the lower respiratory tract, than those cared for at home. More than half of the children were affected by respiratory disease at up to one year of age, compared to about 3% of the children staying at home. Otitis media and conjunctivitis were markedly increased during the first year of life [113]. A Dutch surveillance network of child day-care centres prospectively reported on infectious disease episodes and related use of health care among their child population on a daily basis from March 2010 to March 2012. They found that gastroenteritis and influenza-like illness were the most frequently reported infectious diseases, particularly during the winter months, and that childcare centres reported these infectious diseases to occur twice as often among children aged under two years, compared with children aged two to four years [109]. Other studies have confirmed that the greatest childcare attributable risk is for children under two years old, especially for respiratory and ear infections [108, 114-116].

3.2.1 Respiratory infections, asthma, and ear infections

Childcare is particularly associated with increased levels of respiratory illnesses [10, 108, 110, 113, 117, 118]. In the study by Nafstad et al. in 1996, the three to five year old children in childcare experienced more upper respiratory symptoms and infections compared with children in home care. Approximately 14% of the common cold episodes and 26% of the acute otitis media episodes in this population were estimated to be attributable to childcare centre attendance. The occurrence of recurrent otitis media (13.5% vs 8.1%), recurrent croup (4.5% vs 2.8%), and doctor-diagnosed asthma (9.3% vs 8.6%) was higher in children who sometimes had attended a childcare centre compared with those who had never attended. Without considering the duration of the childcare centre attendance, the risk of recurrent otitis media was strongly related to the starting age, with a decreasing trend in the risk, the higher the age in attendance [108].

Association between respiratory infections and otitis media

The effect of upper respiratory tract (URTI) infections on the eustachian tube and the relationship to otitis media is well documented [119].

Otitis media is classified in two forms [120]:

Acute otitis media (AOM)	An acute symptomatic disease characterized by earache, fever, hearing impairment, and a purulent discharge (otorrhea) through a perforation of the tympanic membrane.

Otitis media with effusion (OME)	An asymptomatic disease involving fluid collection in the middle ear, associated with either a mild or moderate conductive hearing impairment.

AOM is linked to inflammation and blockage of the eustachian tube. A viral upper respiratory infection, in which pathogens from the nasopharynx reach the eustachian tube, causes inflammation, blockage, and negative middle ear pressure. If the eustachian tube remains compromised, pathogens proliferate in the middle ear, causing AOM. In childcare, higher rates of AOM are thought to be attributable to a higher incidence of respiratory tract infections [121].

Alho et al. [122] reported that the risk of chronic otitis media with effusion is highest for a boy who has just had his first birthday, is attending a childcare centre, and has just experienced successive episodes of AOM. Atopy, breastfeeding, family childcare, parental smoking, and the number of siblings did not have a significant influence on the risk after adjustment for their effect on acute episodes. Previous acute otitis media episodes were the greatest risk factor, with each acute episode inducing an increased risk for chronic OME that is highest immediately after the episode and gradually vanishes after three months. Marx et al. [10] found a threefold higher risk for ear infections associated with childcare attendance, and that children cared for at home were much less likely to have ear infections (15.4%) than children cared for at a family day care / babysitter's house (25.2%) or a childcare centre (37%).

That study also found that group size was the greatest risk, rather than attendance alone. Hatakka et al. [123] found an unexpected positive relationship between maternal age and recurrent acute respiratory infections (ARI) and AOM in children, and that maternal academic education increased the child's risk of recurrent ARI or AO. The authors note that maternal educational level is positively associated with an early childcare attendance, and that younger age of childcare attendance is a risk factor for respiratory illnesses. In the New Zealand context, a study by Walker et al. [124] supported factors for chronic OME relating to exposure to infection as being specifically URTI, childcare attendance, and sibling tympanostomy tube placement. There was a small but significant relationship with number of hours per week in childcare (OR per hour/week: 1.03 [95% CI: 1.00–1.05]), and with frequent colds (OR: 2.67 [95% CI: 1.59–4.53]). The authors summarised their finding as,

> Day care attendance exposes children to infection that can lead to chronic OME. Children congregating at childcare increases the transfer of viruses, and the transmission of bacteria that may survive in a biofilm state in mucous secretions on toys and other surfaces

Asthma

In 2014 Cheng et al. [125] reported that previous studies examining possible associations between day care attendance and asthma are conflicting. They found four studies reporting that day care attendance increases the risk of asthma for children of school age, while three studies found a reduced risk of asthma at school age, and two found no association between childcare attendance and asthma at school age. Cheng et al. reported that both the timing and duration of day care attendance in a high-risk cohort might influence the risk of asthma. Cumulative hours of day care attendance in the first year of life less than 1,800 hours were found to increase the risk of asthma in the majority of children. In contrast, cumulative hours of day care attendance in the first year of life exceeding 1800 hours reduced the likelihood of asthma at the age of seven. The 1800-hour threshold is a large number for hours of attendance, especially in the first year of life. To reach this number of attendance hours, a child attending five days a week from one month old would need to attend to 37.5 hours per week for the rest of their first year of life. If they started at 20 weeks old, they would need to attend 55 hours per week. New Zealand Ministry of Education data indicate that only a small percentage of children would attend for more than 1800 hours at less than one year old (see Figure 3, Section 2.1).

3.2.2 Gastrointestinal infections

A 19-month prospective study of children attending 20 day-care centres in the state of Texas, United States, was conducted reported by Pickering et al in 1981. [126] They found that secondary attack rates of diarrhoea in families according to organisms identified in the childcare centre outbreaks were: shigella 26%, rotavirus 15%, and Giardia 17%. The ‘day care home’ rate did not differ significantly from that in households not using childcare. They concluded that childcare centre attendance may play an important role in the epidemiology and transmission of gastroenteritis in the United States.

Another study in the state of Arizona, United States by Bartlett et al. in 1981-82 [127] compared diarrhoeal infection rates in children in 22 childcare centres, with children in of 30 ‘day care homes’ and 102 households not using day care. They reported that the incidence of diarrhoeal illness caused by enteropathogens in infants and toddlers in childcare centres (42 cases per 100 child months), was higher than in ‘day care homes’ (23 cases per 100 child-months), and in households not using childcare (27 cases per 100 child-months) ($p < 0.01$).

A 2008 study in the region of the city of Mersin, Turkey by Özdemir et al. found that 44.4% of the childhood gastroenteritis cases were viral [128]. This study did not relate to childcare attendance, but it does suggest that viral survival and transmission may be important in an ECE and care environment. Rotaviruses are known as a frequent cause of outbreaks of acute diarrhoea in both the general community and in childcare centres and schools [129]. Rotavirus vaccination has been free in New Zealand since July 2014, administered at six weeks, three months and five months of age [130], so the enteric viruses of importance may be transitioning to norovirus, adenoviruses and astroviruses.

Sealy and Shuman reported the results from surveys of 1,731 children for stool ova and parasites (1971 to 1981) in Hampton County, South Carolina. Among preschool-aged children, 42% of white children in Hampton County attended childcare compared with only 4.4% of black children. Each facility in the study served children aged six months to eleven years. They reported that white children in childcare centres experienced Giardia attack rates of 26%, entering the first grade with “at least six times as much infection as those who do not attend childcare.” They stated that a trend toward more giardiasis was linked to white working mothers and childcare, but that the trend had not yet occurred among black preschool-aged children. Sealy and Schuman (1983) [131] stated that:

> ...these results and other epidemiologic data indicate that as few as 100 children can maintain endemic levels of infection in a county of 18,000 residents. Person-to-person transmission in the childcare setting is sufficient to explain this country’s rising rate of stool positivity of infection (8% of all stool specimens submitted to the state laboratory).

A 2010–2013 Dutch study involving 100 childcare centres by Enserink et al. assessed the burden of childcare-attributable diseases, and the risk factors for enteric infections [109, 132]. Of the studies reviewed, this study provided the greatest detail with respect to enteropathogenic species. Gastroenteritis was the most frequently reported infectious disease (387 incidents per 1,000 child-years), ahead of influenza-like illness at (247 incidents per 1,000 child-years). Childcare centres reported these infectious diseases twice as often among children aged zero to two years compared with children aged two to four years. Sixteen hundred children were surveyed up to three years, during which 1,829 gastroenteritis (GE) episodes were reported, and 5,197 faecal samples were analysed. Identified risk factors were: large childcare centre capacity; crowding; having animals; nappy-changing areas; sandpits; paddling pools; cleaning potties in normal sinks; cleaning vomit with paper towels (but without cleaner); mixing of staff between child groups; and staff members with multiple daily duties. Protective factors were: disinfecting fomites[b] with chlorine; cleaning vomit with paper towels (and cleaner); daily cleaning of bed linen/toys; and exclusion policies for ill children and staff.

A subset of 43 centres were instructed to take one faecal sample from 10 randomly chosen children each month (whether symptomatic or not). All faecal samples were tested for the presence of 16 enteropathogenic bacteria, viruses and parasites, including adenovirus, astrovirus, norovirus, rotavirus, sapovirus, *Salmonella enterica*, *Campylobacter jejuni, Shigella spp, Clostridium difficile, E. coli* (*Shigatoxin-producing,* enteroinvasive, enteroaggregative, typical and atypical enteropathogenic), *Yersinia enterocolitica, Cryptosporidium hominis/parvum, Dientamoeba fragilis* and *G. lamblia.* The most common organisms detected were norovirus, rotavirus, astrovirus, *G. lamblia*, and *C. hominis,* in descending order of detection frequency [132] .

Rotavirus infection was associated with mixing of staff across age groups, non-exclusion of children with gastroenteritis symptoms, and hygiene factors. Norovirus was associated with centre population, use of sandpits and paddling pools, and hygiene factors. Astrovirus was associated with toy hygiene. Giardia infection was associated with animals at the centre, the presence of a sandpit, and hygiene factors. Cryptosporidium infection was seasonal and associated with staff having multiple duties. The authors noted that a limitation of the study was having no information on the exposure of children in their home settings, and that household characteristics might be even stronger predictors of GE than the childcare characteristics.

---

[b] Fomites are objects or materials which are likely to carry infection, such as clothes, utensils, and furniture.

3.2.3 Acquired resistance

A number of studies demonstrate some protective effect from exposure to infections in childcare, or suggest that childcare-attributable infections simply shift an inevitable phase of infections earlier in life. In a 1987 study by Hurwitz et al.[133], for the children in each age group currently in childcare, increased duration of past exposure to childcare was associated with a decreased risk of respiratory illness. In a 2008–2012 longitudinal cohort study by Schuez-Havupalo [134], the respiratory infectious disease burden was described as clearly related to out-of-home care, but it decreased within nine months after the start of childcare.

Enserink et al. [135] found that children aged under six years attending childcare centres (but not those in 'day care homes') had an increased risk for hospitalisation due to gastroenteritis from their enrolment up to 12 months of attendance. After 12 months of attendance, attending either childcare centres or childcare homes had a reduced risk of hospitalisation for gastroenteritis, but only if they started preschool before one year of age. They found that this effect did not last into the elementary school years (over six years of age).

Haby et al. [114] found that early attendance at childcare was shown to protect against atopy, as defined by a positive skin-prick test. The authors considered two hypotheses for this association: one a protective effect from increased exposure to infections, and the other an effect from lower levels of exposure to indoor allergens. Details of asthma, eczema, hay fever, childcare attendance, breastfeeding history, maternal smoking during pregnancy, and season of birth were collected by a parent-completed questionnaire, and city of current residence, gender, and number of older siblings were included in the final model. Children who attended childcare before two years of age had a reduced risk of atopy at three to five years. The greatest effect was seen in children who attended a childcare centre (odds ratio (OR), 0.26; 95% CI, 0.14–0.50) rather than 'family day care' (OR, 0.66; 95% CI, 0.41–1.04). The study did not measure environmental allergens, however, and did not draw a conclusion regarding either hypothesis.

Shope [136] stated that "on the basis of strong research evidence, earlier acquisition of immunity develops among children who participate in early care and education programs after the first year or two. In general, early childhood exposure to group settings leads to fewer infections, asthma, and atopic disease at school age, although some important subgroups exist". Shope went on to say that "on the basis of strong research evidence, unnecessary exclusion is common and causes workplace and financial hardships for families. Paediatricians can have a role in reducing unnecessary exclusions".

The evidence is not universal, however, with Nafstad et al.[108] stating that the results of their 1991 study were inconsistent with a hypothesis of the protective effect suggested by Hurwitz et al. In their study, they found that the risk of recurrent otitis media was strongly related to starting age, with a decreasing trend in the risk the higher the age of first attendance (zero to two years, 17.5% (OR: 1.80-3.77); two to three years, 12.4% (OR: 1.17-2.56); three years or over, 11.0% (OR: 1.02-2.14); and never, 8.1%). The lifetime risk of doctor-diagnosed asthma was 11.7% higher for children starting before two years of age (OR: 1.07-2.36) compared with those who started later, or who had not attended day care. These results controlled for sex, birth weight, duration of breastfeeding, siblings, parental education, one- or two-parent family, parental smoking, pets (cats and dogs), home dampness, and parental asthma, but not for duration of childcare attendance. Hagerhed-Engman et al.[137] also found that while attending childcare was associated with an increased risk of symptoms related to airways infections as well with eczema and allergic reactions to food, no sign of protection from day-care attendance for allergic diseases was found up to six years of age. They also found that multiple airway infections and childcare attendance were found to be independently associated with asthma and allergic symptoms. They stated that:

> Our study did not show any protective effect of childcare attendance for any symptom in any age group. On the contrary, there was an increased risk for most symptoms studied, particularly in the lower age groups. Considering the significant increase of the allergic diseases in Sweden over the last decades our findings justify a significant public health concern.

A 1998–2006 study by Côté et al. [138], part of the Quebec Longitudinal Study of Child Development, examined the short- and long-term risks of infections associated with childcare attendance, assessed annually from five months to eight years of age. The authors stated that the results lent some support to the possible existence of a sensitive period during the preschool years, which they defined as birth to age two and a half years, during which time being exposed to large groups of children may protect against future infections. Children who started some form of group care after age two and a half years did not benefit from a protection from exposure during the years up to six years old, and exhibited increased risk of ear infection at the time they started childcare. The authors stated that there was no increased risk of infections in early school years resulting from childcare attendance, but also noted that the long-term protective effect observed for children who started at 'large group childcare' before the age of two and a half years was insufficient to offset the initial increased risk.

Enserink et al. [109] explained that early day-care attendance shifts the occurrence of first infectious disease episodes to an earlier age where complications requiring health care are more likely to arise. As an example, rotavirus infection increases the risk of a type of bowel intussusception, particularly in infants under one year of age [139].

Araújo-Martins et al. [140] suggested that when studying children's illnesses, it might also be important to consider the effect on parents, as diseases could enhance both child and parental stress. They cited evidence that stress induces cortisol release, and that cortisol exerts an inhibitory action over the immune system, while mothers of children with respiratory diseases, such as asthma, have higher levels of parenting stress. Children whose parents experience higher levels of stress show higher vulnerability to respiratory disease. They concluded that cortisol may be one of the biological links between parent-child stress and respiratory disease in childhood.

3.3 Part One continued (two components) – environmental conditions

Environmental management in childcare and early childhood education is particularly complex, with a population that is particularly susceptible to biological risks and chemical and particulate hazards. In addition to the risk factors, the knowledge and behaviour of children, teachers, parents, and advisory or enforcement agencies are also very complex. A thorough treatment of risks, science and practices for childcare environmental management would be vast, therefore in this section the intent is only to highlight the magnitude (great or small) of some of the physical environmental risks.

3.3.1 Crowding and group size

Crowding in childcare has been identified in a review by Heinrich et al. as a risk factor for bacterial infections, with the risk diminishing with increasing space per child [113]. Crowded indoor environments, especially when poorly ventilated, are recognised as representing greater risks for viral transmission [141]. Of the studies described in Section 3.4, four out of five found a positive association between child density per square metre and infection rates.

From a 1985–86 study, Bell et al. [142] concluded that the strongest predictor of illness due to out-of-home care was the number of children in the room, but this was based on type of care (centre-based care, ‘family day care’, relative’s home, ‘mother’s day out’ programme) and parent reporting rather than direct measurements, and did not asses space per person

Crowding and health – New Zealand data

While there have been no previous studies of crowding in childcare in New Zealand, it has been studied in residential dwellings. A New Zealand study in 2007 analysed spring hospital admission data. Longer total stay was more likely in those of younger age, who were either premature, or of Māori or Pacific ethnicity. The study found that exposure to second-hand tobacco smoke, lack of heating, and large households in overcrowded conditions were risk factors for these illnesses in children, consistent with previous findings from other studies [143]. While New Zealand law prevents children being exposed to tobacco smoke in childcare, they may be exposed to crowding and low temperatures.

A systematic review in 2012 by Baker et al. [14] summarised studies from the international published literature that investigated the relationship between exposure to household crowding and the outcome of close contact infectious disease. They reported that for respiratory diseases, two cohort studies of influenza-like illness both found a significant positive relationship between disease risk and household crowding. For children under five years old, household crowding had a significant positive relationship with pneumonia, while for children less than three years old, household crowding increased risk of lower respiratory tract infection. Meta-analysis from three cross-sectional articles indicated that children less than five years old living in more crowded households also experienced a small increase in the risk of gastroenteritis.

Childcare and crowding

A study by Fiedler and Hoyer mentioned space for children in day-nurseries less than $4m^2$ as a risk factor for acute respiratory diseases [144]. The study involved 659 children aged one to two years, but this information is from an abstract only – the original article in German was not found. A Finnish study by Pönkä et al. [107] (see Section 0) found that a smaller area per child in childcare was correlated with a higher incidence of bronchitis among children under three years of age, although the method of calculating area per child, and whether it was activity space or total space, was not described. A larger total number of children at a childcare centre was correlated with higher incidences of tonsillitis and diarrhoea; however, the volume of air in childcare centres did not correlate significantly with morbidity.

A study by Marx et al.[10] in the United States tested the hypothesis that size of the childcare group is an important variable in ear infection risk for children aged one to two in childcare. They found that size of the childcare group rather than childcare attendance is the "primary modifiable risk variable" in relation to childcare. The size of the childcare group was determined by asking the question, "How many children are usually cared for together, in the same group, at the same time? Do not include children in the entire school or program." They found that a linear relationship exists between the size of the childcare group and the percentage of frequent ear infections reported by the caregiver. "Frequent ear infections" varied from 16.4% in "small childcare groups" to 30.4% in "medium childcare groups" and 35.5% in "large childcare groups." Compared with "small childcare groups," the risk of frequent ear infections in medium childcare groups was 2.18 times greater (95% CI: 1.52 to 3.12), and for a child in a large day-care group, 4.7 times greater (95% CI: 3.28 to 6.87). Of the studies detailed in Section 3.4 (three component studies), Alexandrino et al. [145] reported that the risk of upper respiratory tract infections increased with decreased space per child (OR = 0.434, 95% CI = 0.206–0.914), and Rindel et al. [146, 147] reported that sickness will decrease by 10.8% for each square metre increase in the playroom area per child (abstract only, no confidence interval provided).

The 2010–2013 Dutch study by Enserink et al.[132] (see also Sections 3.2.2 and 3.4.3) found a significant risk of gastroenteritis associated with increased crowding (calculated as percentage of maximum allowable occupancy rather than m^2 per child).

Although not a study in relation to infections, a Danish study by Kirkeby et al. [148] is worth a mention in relation to crowding effects. The research project investigated the way more or less space influences daily pedagogical practice. Twelve interviews were conducted with experienced teachers from twelve different kindergartens with different amounts of space, varying from a ratio of $2.1m^2$ play area per child to $5.5m^2$. The results indicated that, for a group of children with special needs in particular, sufficient space was “crucial.” They reported that, according to the teachers, a low space:child ratio meant that children got too close to each other, and that there was more unrest, more noise and more conflict. Sufficient space meant that some conflicts could be avoided.

Another Danish study in 1991–92 by Mygind et al. [149] considered the effect of children spending time outdoors. The study tested the hypothesis that increasing the amount of time spent outdoors could lower the incidence of illness. Two study groups from eight childcare centres had a two-month period in which the percentage of time spent outdoors per day for one group was almost double that of the other study group. The study found no significant effect of spending more time outdoors on the number of illness episodes, length of the episode, or cause of illness. The authors concluded that their findings were consistent with the theory that illness among childcare children is largely a result of contact among children and the hygiene standards of the institution.

3.3.2 Temperature, humidity and meteorological conditions

Survival of viruses in the air and on surfaces is related to the type of virus, with many showing longer survival or transmissibility in cooler, dryer conditions, but this is not the case for all viruses, and the temperature/humidity interaction may be complex. In a 2005 review of mechanisms of droplet spread and viral survival, Morawska [150] concluded that viruses with a lower lipid content have higher stability at high relative humidity (RH) than lipid-containing viruses, and that while lipid-enveloped viruses are more stable in dry air, the converse is true of non-enveloped viruses. The lipid envelope is stabilised at lower temperatures. Lipid-enveloped viruses include influenza, parainfluenza, RSV, and corona viruses, while non-enveloped viruses include rhinoviruses, and the gastrointestinal viruses: rotaviruses, adenoviruses, noroviruses and enteroviruses. Rhinoviruses and rotaviruses both survive better at high relative humidity. It is generally the case, however, that cooler temperatures favour viral survival for both enveloped and non-enveloped viruses. Lower temperature (4°C, compared to 20°C) has been shown to improve the survival of astrovirus and adenovirus, but not rotavirus. Astrovirus is sensitive to high humidity, especially at 20°C [151].

Consistent with an enveloped virus, incidence of RSV is correlated with low environmental temperature. In a study by Chen et al.[152], the monthly number of RSV cases decreased by 11.25% (95% CI: 5.34% to 16.79%) for every 1°C increase in the average outdoor temperature. Parainfluenza-3 decreased with high temperature. Activity of adenovirus, which is non-enveloped, was correlated with high total rainfall. Influenza-A activity, however, was correlated with both low temperature and high relative humidity. In a 2010–2011 study by Cui et al.[153], the detection rates of lipid-enveloped airborne viruses Parainfluenza 3 (PIV3), RSV, Influenza A and adenoviruses were negatively associated with temperature and were highest at environmental temperatures between 5°C and 15°C, but the authors note that other studies have found higher temperatures associated with increased PIV3. The generalisation of these studies is limited by use of daily environmental temperatures rather than room temperatures, and the infection rates may be due to factors other than viral survival or viability.

A 2014 systematic review of research into indoor housing temperatures by Jevons et al. [154] included a paper from the United Kingdom and papers from countries with similar climates to the United Kingdom. They concluded that health effects in the general population start to occur below 18°C. They also concluded that effects in older people are more profound than in younger adults, and that there is a lack of information currently available on the impacts of indoor temperature thresholds on children. They did conclude, however, that increasing indoor temperatures may have small (and statistically significant) impacts on children's health.

Metz et al.[155] have reviewed an emerging hypothesis and some early supporting evidence that low absolute humidity (AH) is a key causal factor in winter-time influenza peaks in temperate climates. Following this review, they proposed that humidifying indoor air in classrooms, doctors' consulting rooms or hospital waiting-rooms might reduce rates of influenza transmission. They noted, however, that care would need to be taken to avoid problems with condensation, with the associated risk of fungal growth.

The hypothesis that increasing AH may reduce influenza rates contrasts with a review by Paynter to consider the hypothesis that while the cooler, dryer conditions of temperate climates encourage droplet transmission of RSV and influenza, the warmer, humid conditions of tropical rainy seasons may encourage surface contact transmission of viruses. The proposed mechanism is an increase in the amount of virus that is deposited on surfaces, which increases virus survival in droplets on surfaces [156]. The review reported that while RSV and influenza peak in winter in temperate climates, these infections peak in the rainy season in tropical climates. Paynter found evidence that suggests that increased incidence of influenza and RSV in tropical rainy seasons may be due to increased contact transmission. The review found that some studies found a monotonic relationship, with decreasing influenza virus persistence in artificially produced aerosols with increasing RH, but other studies found a U-shaped function of viral persistence with increasing humidity, with maximum virus persistence at low RH, minimum persistence at 40–60% RH, and moderate persistence at higher RH (tested up to 80%). The review mentioned a study examining influenza survival over 2½ hours in 0.1µl droplets placed on glass slides at room temperature, which found that survival was lower at 84% RH compared to 24% RH, but survival was greatest at 100% RH. At 100% humidity, the influenza virus suspension placed on the slides was still wet after 2½ hours, suggesting this was why the virus remained viable.

The relevance of these findings to childcare and early childhood education in temperate climates relates to the wetting of surfaces. While humidity is less than in tropical climates, wet surfaces, by reason of children's activities, children's wet hands after handwashing, and the cleaning of surfaces, may encourage viral survival on surfaces. In a maritime temperate climate such as New Zealand, cooler indoor temperatures, especially in winter, combined with humidity commonly in the range of 60% to 80%, may slow drying of surfaces and encourage surface viral survival.

In a systematic review of viral survival on soft surfaces, Yeargin et al.[157] found that the effect of RH on virus survival varied, particularly by virus type and temperature. The authors also noted that nonenveloped viruses survived better at higher RH compared with enveloped viruses that favour lower RH, but they noted that, theoretically, high RH could limit evaporation and desiccation and therefore positively influence the survival of nonenveloped viruses. The literature supported the view that, generally, viral survival is inversely related to temperature, but the temperature increments measured were all discrete and widely spaced: for example –20°C, 4°C, 18°C, and 30°C.

A study by Zarkov and Urumova [158] investigating Influenza A (H6N2) survival in duck faeces found that, at constant humidity, the virus persisted until fourteen, six, and two days at 4°C, 15°C, and 22°C respectively. The reduced survival between 15ºC and 22ºC relates to New Zealand indoor temperatures, but the other conditions of the experiment may not be generalisable to normal surface conditions in a childcare centre.

Other temperature-related factors

Shaw Stewart [159] states that, "Today, incontrovertible evidence shows that ambient temperature dips and host chilling increase the incidence and severity of viral acute respiratory tract infections." Shaw Stuart explains that host chilling may activate dormant viruses including influenza viruses, adenoviruses and varicella zoster (chickenpox virus), and that this mechanism seems to be the main driver of seasonality, along with the mechanism of chilling-induced host susceptibility. Relative humidity is associated with rainfall, which can wet individuals' clothing, and thus induce chilling.

In a New Zealand study, Pierse et al [160] found that small changes in indoor temperature were associated with small changes in the lung function of asthmatic children. Exposure to temperatures below 12°C had the greatest effect on lung function.

3.3.3 Bacterial, viral, fungal and endotoxin environmental loading and transmission

Viral transmission and environmental loading

Paynter [156] described three main routes for transmission of respiratory viruses:

Direct contact:	Large respiratory droplets can travel short distances and deposit on mucous membranes of the respiratory tract.

Indirect contact: Droplets will also deposit on surfaces where the virus may persist for long enough to be transferred to mucous membranes (indirect contact).

Aerosol transmission: Small respiratory droplets can form droplet nuclei, which are small enough to be inhaled, and can remain suspended in the air for hours.

The relative importance of each of these three routes varies between different infections, and for a particular infection the relative importance of each route is also likely to vary according to the setting and ambient conditions. RSV appears to be predominantly spread by direct and indirect contact through large respiratory droplets, so virus survival on surfaces is likely to be the more important factor. Influenza appears to spread by all three routes, so viral survival both in aerosol and on surfaces is important.[156]

A review by La Rosa [141] found that the major respiratory viruses (influenza, RSV, rhinovirus, adenovirus and coronavirus) can all be spread by aerosols. RSV can spread long distances indoors, and has been detected in the air at seven metres from a host in a hospital setting. La Rosa states that transmission rates up to 100% have been shown to occur in childcare centres, with the most common transmission route being surface contact with contaminated surfaces.

Large respiratory droplets travel only short distances (1–2 metres) before settling on surfaces, where viruses can remain infectious for hours or days. These droplets do not remain suspended in the air, but airborne transmission depends on virus-containing droplet nuclei (small-particle residue $\leq 5\mu m$) of evaporated droplets or dust particles, that can remain suspended in the air for long periods. Virus survival on fomites is influenced by temperature, humidity, pH, and exposure to ultraviolet light. Secondary aerosolization can occur when air displacements disperse the viruses back into the air from contaminated surfaces. Rhinovirus aerosols can be generated by coughing, sneezing or just breathing, with infection risk simply from being in the same room as an infected person [141].

Environmental bacterial and viral loading in early care and education

A study by Brągoszewska et al. [161] published in December 2015 measured airborne bacterial loading in a nursery school in Gwilice, Poland, and the bacterial loading in the external air. The level of culturable bacterial aerosols indoors was six to eight times higher than outdoors. In the classrooms, respirable bacterial particles contributed up to 85% of the total number of culturable bacteria. A comparison of the species in the indoor samples (predominantly gram-positive cocci) and outdoor samples (gram-negative cocci) indicated that most of the bacteria present in the nursery school were of human origin. The bacterial dose inhaled by the staff in the school was 1.5–1.9 times higher, and the dose inhaled by younger children was 3.0 times higher, than the dose absorbed by adults inside apartments in Katowice, Upper Silesia, relative to body weight. The authors stated that this result suggests the elevated risk of adverse health effects in younger children exposed to the bioaerosols in the nursery school, including infections. While the dose for staff compared with apartment dwellers was higher, the younger child dose will have been largely a result of body weight. It should be mentioned, however, that the dose as calculated in relation to body weight may have a complex and non-linear relationship to morbidity risk. This study was limited by a small sample size, and the authors noted that studies of bioaerosols tended to show a great variation in concentration.

Consistent with the findings of Brągoszewska et al., Prussin et al. [162] examined the microbiological communities present in filters from the heating, ventilation, and air-conditioning (HVAC) system of a childcare centre every two weeks over the course of a year. Clear seasonal differences in the microbial community were not evident, but the microbiological community structure differed when the childcare centre was closed and unoccupied for a 13-day period. These results suggest that human occupancy, rather than the environment, is the major driver in shaping the microbial community structure in the air of the childcare centre.

The ENVIRH study [163] (see Section 3.4.1) found total bacteria concentrations 57 times higher in nurseries and 52 times higher in kindergarten than outdoors during spring, although likely origins by species were not described. Fungal loading results were all above the national reference values in nurseries and kindergarten classrooms, presenting a highly significant difference between seasons.

In the 2011–12 Norwegian SIB study [164] (see Section 3.4.4), environmental sampling was undertaken to identify viral and bacterial loading in a childcare environment. Coliform bacteria were primarily found in the toilet and kitchen areas whereas nasopharyngeal bacteria were found mostly on toys and fabric surfaces in the playroom. Respiratory viruses were omnipresent in the childcare centre environment, especially on the toys. The most prevalent virus was bocavirus (present on 81% of the sites), followed by coronavirus (77%), adenovirus (46%), and rhinovirus (29%). Other respiratory viruses such as parainfluenza, parechovirus, and influenza B were rarely found, if found at all. The virus with the highest prevalence was astrovirus (12%), followed by rotavirus (2%), and norovirus species (0.7–1.5%).

Endotoxins

Endotoxins are lipopolysaccharide components of the outer membranes of gram-negative bacteria. Endotoxins in settled dust in residential environments has been associated with an increase in asthma symptoms, asthma medications, and reductions in lung function in those with atopy or asthma. A positive relationship between increased endotoxin concentration and excess illnesses per year was found by Dales et al.[165]. They reported that, accounting for fungal exposure as a potential confounder, doubling air endotoxin was associated with an increase of 3.25 illness days per year, adjusted for age, year of study, breastfeeding, childcare attendance, indoor temperature, and gender. Airborne endotoxin levels can be expected to rise with occupancy rates and activity, especially when cleaning is neglected.

3.3.4 Ventilation, CO_2 and stratification

A systematic review by Li et al.[166] considered articles from 1965 to 2003, using the MeSH terms ventilation, airflow, airborne, droplet, droplet nuclei, aerosol, bioaerosol, transmission, survival, infectivity, nosocomial, tuberculosis, measles, influenza, varicella, smallpox, SARS, common cold, anthrax, respiratory, inhaled, and communicable diseases. They concluded, "...that there is strong and sufficient evidence to demonstrate the association between ventilation, air movements in buildings and the transmission/spread of infectious diseases such as measles, tuberculosis, chickenpox, influenza, smallpox and SARS."

They did not find sufficient data to specify and quantify the minimum ventilation requirements to reduce or prevent spread of infectious diseases via the airborne route, for example in offices or classrooms.

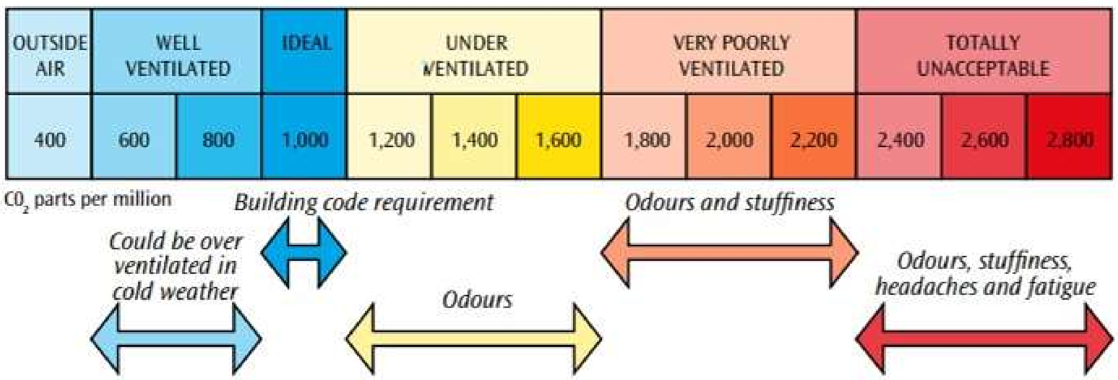
The results from Phase 1 of the ENVIRH study (Section 3.4.1) showed a small association between childcare indoor CO_2 concentration and wheezing in the previous 12 months [167]. Concentrations of CO_2, total bacteria, and gram-negative bacteria were associated with low airflow rates [163], but the study did not provide evidence for association between infections and ventilation. The results of the SIB study [168] (Section 3.4.4) did show an association between ventilation rates and child illness rates, but not for specific infections.

Zhou et al.[105] have explained that two important flow elements related to both the long-range and short-range airborne routes of infection are exhaled flow (from breathing, coughing, sneezing or talking) and ventilation airflow. In their 2017 paper they described use of jet mechanics (mathematical modelling) matched to previous physical dispersion experiments to investigate the dispersion of the exhaled flow in thermally stratified indoor airspace. They illustrated from Qian et al. [169] that oscillating horizontal flow can occur below the stratification level in these environments. A cough or sneeze jet can transport a long distance in the stratified layer and may be trapped within it. They explained that thermal stratification could occur in rooms with displacement ventilation, with underfloor air conditioning, natural ventilation, and in an enclosed room without ventilation. They stated that their findings could be useful to indoor air environment studies with respect to control of airborne pollutants, such as “transmission of diseases and airborne exposure of pollutants by young children at homes,” and that their study shows a need for care with stable thermally stratified layers in higher-risk environments (e.g. hospitals) because of infection transfer risk. This research is especially relevant to childcare sleep rooms (often pre-heated), in which children may be sleeping in very close proximity with little or no room ventilation or internal air disturbance.

Physiological and psychological responses to elevated CO_2 levels

CO_2 levels of 1,000–2,000ppm may result in complaints of drowsiness and perception of poor air quality. Levels of 2,000–5,000ppm can cause headaches, sleepiness and a sensation of stagnant, stale or ‘stuffy’ air, as well as poor concentration, loss of attention, increased heart rate and slight nausea [170]. BRANZ has provided guidelines for schools using CO_2 as a proxy for ventilation, as shown in Figure 18.

Figure 18: Carbon dioxide as an indicator of school classroom ventilation, reproduced from *Designing Quality Learning Spaces: Ventilation & Indoor Air Quality* [171].



A study by the US Department of Energy's Lawrence Berkeley National Laboratory found that:

> On nine scales of decision-making performance, test subjects showed significant reductions on six of the scales at CO_2 levels of 1,000 parts per million (ppm) and large reductions on seven of the scales at 2,500 ppm. The most dramatic declines in performance, in which subjects were rated as "dysfunctional," were for taking initiative and thinking strategically [172].

Effects of high CO_2 levels on decision making performance may not be serious for very young children in the short term, but the implications may be very important for teachers in that environment.

New Zealand school performance requirements for CO_2 levels

The New Zealand Ministry of Education has specified CO_2 level maxima for schools, but not for Early Childhood Centres [173]. For schools the performance requirements are:

- the average concentration of CO_2 should not exceed 1,500ppm when measured at seated head height (1,200mm), during the continuous period between the start and finish of teaching on any day

- the maximum peak concentration of CO_2 should not exceed 3,000ppm during the teaching day
- at any occupied time, the occupants should be able to purge air to lower the concentration of CO_2 to 1,000ppm within 10 minutes
- a purge threshold of 800ppm or lower is recommended.

3.3.5 Chemical and particulate effects

There is increasing evidence that particulate air pollutants, such as diesel exhaust particles, are associated with chronic inflammatory processes and illness of the respiratory tract [174, 175]. Exposure to volatile organic compounds is related to immunologic, respiratory, and carcinogenic health effects [167]. Short-term increases in $PM_{2.5}$, PM_{10} and ozone (O_3) have been associated with airway inflammation for school-age children independent of asthma and allergy status [86]. In New Zealand it is not uncommon for childcare centres to be located on arterial traffic routes (see Section 2.8) or in commercial or industrial zones.

Potential mechanisms by which polyaromatic hydrocarbons (PAHs) or $PM_{2.5}$ may increase lower respiratory tract illnesses include oxidative stress, structural damage, efficient transport of pathogenic microbes, and immune dysregulation. PAH constituents of diesel exhaust particles catalytically generate reactive oxygen species, causing stress to biological systems [176]. A study in the Czech Republic [176] demonstrated strong associations of PAHs with lower respiratory tract illnesses, especially bronchitis, in children between birth and four and a half years of age. Ambient PAHs and fine particles were associated with early-life susceptibility to bronchitis. Associations were stronger for longer pollutant-averaging periods and, among children younger than two, for PAHs compared with fine particles. Preschool-age children may be particularly vulnerable to air pollution-induced illnesses.

A Malaysian study published by Choo et al. in 2015 [177] comparing air quality in urban, suburban and rural ‘preschools’. Urban ‘preschools’ recorded the highest concentration of carbon monoxide (CO), PM_{10} and $PM_{2.5}$, and the prevalence of cough and wheezing was significantly higher among pre-schoolers from urban area preschools than rural ‘preschools’. Results showed that there was a significant association between cough and indoor CO, PM_{10} and $PM_{2.5}$. The authors concluded that exposures to poor IAQ might increase the risk of respiratory symptoms among preschool children. Road traffic and emissions from the industrial activities nearby were considered to be the main source of PM_{10} and $PM_{2.5}$ for urban preschools. The authors note that construction work such as the repair of roads and highways was present in the urban area.

Indoor air quality and health effects below regulatory guideline concentrations

The ENVIRH study [163] found PM_{10} median levels above the national reference levels in nurseries and kindergartens, and peak total volatile organic compound (TVOC) kindergarten values that were of concern. Each increment of 100µg/m^3 of TVOC was associated with wheezing in the previous 12 months. Children exposed to fungal concentration above the 75th percentile had also higher odds of wheezing at follow-up, but TVOCs were associated with wheezing in children with either negative or positive asthma predictive index (API). In the multivariate analysis, a tendency was found for TVOC to be associated with wheezing during or after exercise [167]. The authors noted that high values of PM_{10} concentration found in the childcare centre were probably a consequence of children’s activities that induce particulate matter resuspension.

Several studies have shown that exposure to ambient air pollution at levels below the limits set by current regulatory standards are associated with significant adverse effects on children’s respiratory health. Adverse effects include deficits in lung growth, bronchial symptoms, and development and/or exacerbation of asthma [86]. A 2006–2008 systematic review [178] analysed the association between exposure to specific indoor air pollutants and respiratory disease among children under the age of five. The authors concluded that indoor pollutants, even at the moderate levels found in the developed countries, could be harmful to the respiratory health of very young children. Nevertheless, due to the small number of studies found, the diversity of the pollutants discussed, and the heterogeneous methodology used, they could not regard the evidence linking these pollutants to respiratory problems as conclusive.

A study in Perth, Western Australia by Rodriguez [179], found relationships between O_3 concentrations and raised body temperature, CO and wheeze/rattle and runny/blocked nose, NO_2 and cough and $PM_{2.5}$ with cough. These associations were observed even though air pollutant concentrations were below national standards throughout the study period.

A Brazilian study by Moura [180] also found associations between outdoor air pollution and the number of emergency paediatric consultations, in spite of the fact that the levels of all pollutants monitored during the study period were below recommended levels. The Brazilian study measured effects for PM_{10}, SO_2, NO_2, CO and O_3, but only found statistically significant effects for O_3 and CO.

3.3.6 Hygiene, hands and fomites

There are a number of hygiene-related activities in childcare associated with infection control, including toileting procedures, handwashing procedures, cleaning practices for a wide range of items and surfaces, food and drink hygiene, nasal hygiene, and the use of sandpits, water play, playdough and dress-up clothes. Into this mix there is a wide range of children's behaviours and understanding, ranging from the mouthing behaviours of very young children, to learning of routines by older children.

In a study of childcare hygiene practices and illness outcomes in Helsinki by Pönkä et al. in 2000 [181], hygiene interventions reduced the absences due to infections by 26% among under three year olds, but not among older children. The effect of the intervention was statistically significant for absences due to upper respiratory tract infections and diarrhoea, but observed reduction for otitis media and conjunctivitis were not statistically significant. The study used a baseline questionnaire followed by intervention in a range of hygiene procedures, but the procedures were not described in detail.

Hygiene and diarrhoeal illness

Hygiene problems were reported in the Dutch study by Enserink et al. [109, 132], with 34% of childcare centres not always washing the hands of children before eating, or after a toilet visit (15%), or not always cleaning the toilet and kitchen areas on a daily basis (17%) The study also reported increased risk for gastrointestinal infection rates from the presence of sandpits and/or a paddling pool; having a dedicated nappy (diaper)-changing area; cleaning children's potties in a non-dedicated sink; cleaning vomit with paper towels (but without cleaner); mixing of staff members between different child groups; allowing staff members to have multiple daily duties; and the presence of farm animals or pet animals. The authors suggested that the increased risk from dedicated nappy-change areas may occur because most children have to pass through these areas several times a day, so they could be considered as 'hubs' for transmission of enteropathogens. Identified protective factors were cleaning vomit with paper towels and cleaner, using chlorine as disinfectant for fomites, and daily cleaning of bed linen and toys.

Lemp et al. [182] reported a significant positive correlation between diarrhoea incidence in childcare centres and each of the following variables reported by: average frequency of diapering; average frequency of working with children less than two years of age; average frequency of meal preparation; average frequency of serving food to the children; and percentage of staff who both change nappies and either serve food or prepare meals daily. Centres in which one or more staff members prepared meals, served food, and changed nappies on a daily basis had a 3.28-fold incidence of diarrhoea compared with centres in which staff did not do both food preparation or service and nappy change.

Hygiene and respiratory illness

A review by Serra in 2012 [183]. searched for intervention studies (published in Spanish and English) at childcare centres that evaluated the effectiveness of respiratory disease prevention recommendations. No study analysed the effect of a single measure, and no publication related to breastfeeding or the exclusion of symptomatic subjects was found. The results were not consistent among the various studies, and only one study showed a low risk of bias. All studies resulting from the search referred to hand hygiene, cleaning of the environment, and nasal hygiene, and five of the articles described different training approaches. The study also looked for national-level guidelines, but it was limited to a Google search using the terms 'guidelines', 'statement', 'recommendations', 'day care', 'childcare' and 'infection prevention'. In the review for this chapter, the term 'preschool' in a Scopus search returned the most articles, but in New Zealand the preferred term is 'early childhood education'. The New Zealand Ministry of Health resource for early childhood services, *Nga Kupu Oranga,* would not have been found with the terms used by Serra.

Surface contamination and fomites

The risk of surface and object contamination is much higher in childcare and early childhood education than in most other work or social settings. The combination of behaviours, lack of personal hygiene awareness in very young children, and developing immune systems may contribute to surface contamination and acquisition of infections by surface contact. Surface survival of microorganisms may be as important as, or more important than, droplet or aerosol survival.

Temperature and humidity are discussed as factors in viral survival time in Section 3.3.2, but the type of surface is also important for viral survival. Bean et al.[184] found that influenza A and influenza B viruses survived for prolonged periods of time on the hard, nonporous surfaces of stainless steel and plastic. Complete drying of the virus inocula on these surfaces occurred in 1.5 hours. They found that viruses remained viable for much shorter periods on the highly porous surfaces such as cotton or paper, becoming undetectable by 8–12 hours in most cases. Drying occurred on these surfaces in 5–15 minutes. Viable virus that was transferred from tissue to hands declined to barely detectable levels in 15 minutes. These studies were conducted with ambient temperatures of 26.7–28.9°C, with relative humidity ranging from 35% to 56%, so these results may not be generalisable to the autumn to spring conditions in most New Zealand childcare centres.

Antimicrobial use and bacterial resistance

Greenberg et al.[121] expressed a concern that childcare provides an ideal environment for the development of antimicrobial resistance. They propose that large numbers of children, frequent close person-to-person contact, and wide use of antimicrobials[c] provides the selection pressure that favours the emergence of resistant organisms. They stated that children attending childcare centres frequently carry antibacterial-resistant organisms in their nasopharynx, leading to AOM that may be refractory (temporarily unresponsive) to antibacterial treatment.

---

[c] Antimicrobials are substances that can kill or reduce activity of microorganisms, and may have action against fungi or viruses as well as bacteria. An antibiotic is an antimicrobial that kills or inhibits the growth and replication of a bacterium.

3.4 Part Two (three components) – studies investigating early care and education physical environments with health outcome measures

The literature search found only 14 papers (Table 5) describing studies that measured early care and education physical environments and health outcomes, that were of direct relevance to the review scope. These 14 papers relate to eight studies. The risk factors investigated in these studies are shown in Table 6. There were other papers related to these studies, but they dealt with topics outside the scope of this review, for example phthalate levels in dust, or home environments.

3.4.1 The Environment and Health in Children's Day Care Centres Study – ENVIRH (Portugal)

The ENVIRH study was a two-phase study in Lisbon and Porto, the first phase taking place from October to December 2010. The aim of the study was to investigate the association between asthma and wheezing, and exposure to volatile organic compounds (VOCs), particulates, house dust mite allergens, moulds and bacteria in childcare centres. The literature search found four papers published in English from the study, (the first four papers listed in Table 5).

The study used the full Portuguese version of the International Study on Asthma and Allergies in Children (ISAAC) questionnaire. The ENVIRH study focused on indoor air quality rather than crowding and temperature / relative humidity (RH). Phase 1 assessed building characteristics, indoor CO_2, temperature and RH in 45 childcare centres, with a total population of 5,161 children. The study received 3,186 child health questionnaires: a 61.7% response.

In Phase 2, 20 childcare centres were selected from the Phase 1 cohort. The second phase consisted of two detailed evaluations, one in spring 2011 and other in winter 2011–2012, involving 1,221 and 667 children respectively. Data were collected on indoor air quality (IAQ), thermal comfort parameters, respiratory and allergy-related health, airway inflammation biomarkers, viral respiratory infections, and parental and child stress [140].

Table 5: Studies involving environmental measures and health outcome measures

Location	Authors	Most relevant papers	Publication date
Portugal	Carreiro-Martins, P. et al.	Effect of indoor air quality of day care centers in children with different predispositions to asthma	2016
Portugal	Araujo-Martins, J. et al.	Environment and health in children's day care centers (ENVIRH) – Study rationale and protocol	2014
Portugal	Carreiro-Martins, P. et al.	CO_2 concentration in day care centres is related to wheezing in attending children	2014
Portugal	Mendes, A. et al.	Environmental and ventilation assessment in child day care centres in Porto	2014
Portugal	Alexandrino, A.S. et al.	Risk factors for respiratory infections among children attending day care centres.	2016
Netherlands	Enserink, R. et al.	Risk factors for gastroenteritis in child day care	2015
Denmark	Kolarik, B. et al.	Ventilation in day care centres and sick leave among nursery children	2015
Denmark	Clausen, G. et al.	Children's health and its association with indoor environments in Danish homes and daycare centers (IECH study) – methods	2012
Denmark	Clausen, G. et al.	Indoor environments and children's health in 151 Danish kindergartens	2009
Norway	Nafstad, P. et al.	Day care centre characteristics and children's respiratory health	2005
Denmark	Rindel, A.K. et al.	Significance of playroom area for illness among children in daycare centers	1997
Denmark	Rindel, A.K. et al.	Morbidity of children attending daycare centers in Copenhagen illustrated by social, physical, environmental and hygienic factors	1992
Finland	Pönkä, A. et al.	Infections and other illnesses of children in day-care centres in Helsinki I: Incidences and effects of home and day-care centre variables	1991
Germany	Wirsing, A . et al.	Interior climate and acute respiratory diseases in crèches	1985

Table 6: Risk factors reported in three-component study findings

	Study name	ENVIRH				IECH			Helsinki 1	
	Study location	Portugal	Portugal	Netherlands	Denmark	Denmark	Norway	Denmark	Finland	Germany
	Lead authors	Araujo-Martins Carreiro-Martins Mendes	Alexandrino	Enserink	Kolarik	Clausen	Nafstad	Rindel (abstract)	Ponka	Passauer Wirsing (abstract)
Reported results (as opposed to parameters measured)	Crowding		Yes	Yes		Yes		Yes	Yes	
	Population in childcare		Yes	Yes			Yes			
	Temperature	Yes				Yes				Yes
	Humidity					Yes				
	CO_2 or ventilation*	Yes			Yes	Yes			Yes	
	Other air quality				Yes	Yes				
	Other building characteristics	Yes					Yes			
	Illness / absence data source	Retrospective previous 12 monthsfrom ISAAC questionnaire to childcare centres	Prospective parent data with GP diagnosis	Prospective from national surveillance system and laboratory reports	Retrospective childcare centre data one year earlier	Retrospective case-base from parent questionnaires and GP diagnosis	Retrospective parent questionnaire previous 4 weeks and 12 months	Not known (abstract only)	Absence data from childcare centres, illness data prospective from parents	Not known (abstract only)
	Absence rates				Yes	Yes		Yes	Yes	
	Specific illness rates	Wheezing only	Only 'healthy / unhealthy' for URTI, LRTI and AOM	Enteric infections by organism		Asthma, rhino-conjunctivitis, and atopic eczema	Respiratory and otitis media		Respiratory, eyes, ear and enteric infections	Respiratory

*Nafstad et al. reported on ventilation types, but not ventilation rates

The Phase 2 winter-spring studies were conducted in a maritime climate with February high/low temperatures of 5ºC/15ºC (Porto) and 8ºC/14ºC (Lisbon). Median indoor temperatures were 19.5ºC (P_{25}-P_{75} 18.1–20.6ºC), while average indoor relative humidity was 54.6% in Phase 1 and 60% in Phase 2. No significant association was found between wheezing and temperature or RH. Children attended 6–10 hours per day [163], while room loadings were recorded as 12–19 children in areas of 28.7 to 40.1m^2 [185]. The ENVIRH papers did not provide area per child, but the measurements provided indicate that some children were in rooms with 2.1m^2/child or less. Another study in Porto recorded space per child in Porto centres as 1.61–5.24m^2/child [145]. The study included children under two years of age.

The results from Phase 1 found a small association between childcare indoor CO_2 concentration and wheezing in the previous 12 months. In Phase 1, median indoor CO_2 was 1,440ppm (P_{25}-P_{75} 1,085–1,970ppm), while Phase 2 median indoor CO_2 was lower at 1,221ppm (P_{25}-P_{75} 770–1,536ppm). The authors noted that a major drawback of the study in relation to CO_2 was the use of point in time rather than continuous measurements. The study also found that indoor CO_2 concentration was related to the number of children in each room, although the area or volume per child was not given in the results. Indoor CO_2 levels were inversely proportional to opening windows and internal doors, and higher wind velocity. Only 33% of childcare centres had windows open during the Phase 2 visits [185]. One of the Phase 2 studies found an association between wheezing and indoor air quality (IAQ) for children with and without a predisposition to asthma. In addition to CO_2, total volatile organic compounds (TVOC), fungal concentrations and house dust mite allergen (Der p1/g dust) were associated with wheezing in the previous 12 months. The authors noted that as IAQ measurements were not performed in children's homes, control for conditions in the children's homes was reliant on the ISAAC questionnaires [167].

The other Phase 2 study described indoor conditions in detail, without drawing correlation with wheezing. The study found levels of CO_2, PM_{10}, TVOC, and total bacterial concentrations well above the Portuguese reference levels. Bacterial concentrations indoors were described as 30 times higher than outdoors in winter and 50 times higher than outdoors in spring.

Mendes et al. suggested that high median and maximal levels of CO_2 found in the Phase 1 study may have been due to "overcrowded classrooms" and inefficient ventilation [163]. Increased bacterial concentrations, PM_{10} and airborne dust may be associated with crowding.

3.4.2 Porto and Lisbon study of risk factors among children attending day care studies (Portugal)

Another study in Porto, Portugal, published in 2016 by Alexandrino et al. [145], and not part of the ENVIRH study, included crowding as a risk factor for illness. The study assessed childcare risk factors for upper and lower respiratory tract infections (URTI and LRTI), as well as acute otitis media (AOM), and described the association between these outcomes and crowding rates described in m^2 per child. Area per child provision ranged from 2.0 to 4.45m^2 per child.

From an available cohort of 220 children from six randomly selected childcare centres, 201 were given parental approval for participation in the study, and of these 152 were eligible to participate following study inclusion/exclusion criteria. The study was conducted in winter (January to March) and involved children up to three years of age.

The study considered four categories of independent variables:

i) maternal – age, education, smoking during pregnancy, breastfeeding
ii) household-related – occupancy, siblings, smoking, parents' history of respiratory diseases
iii) child-related – age, gender, weight, height, BMI, birth statistics, use of a pacifier
iv) childcare-related – crowding, children per room, personal and general hygiene

Data for the first three risk factor categories were obtained from a questionnaire provided to the parents for the one-month period prior to survey date. The childcare-related risk factor data (questions regarding premises and practices) were obtained from a questionnaire provided to childcare employees responsible for each child. Diagnosis of illness was dependent on caregivers' reports, followed by diagnostic parameters used by the child's doctor.

The authors stated that they found no significant associations between the measures in the parent questionnaires and URTI, so only childcare-related risk factor results were reported. Results for illness outcomes were expressed as prevalence during the three-month study period rather than event incidence, i.e. "healthy" or URTI/LRTI/AOM, but not as frequency of illness. Using logistic regression, the study analysis compared cases with non-cases in 25th to 75th frequency quartiles for each of URTI, LRTI and AOM, describing the conditions experienced by each group. The study found that the risk of URTI increased as the area per child decreased (OR = 0.434, 95% CI = 0.206–0.914) and as the disinfection of WC/diapers-change increased (OR = 2.56, 95% CI = 1.089–6.017. Surprisingly, they also found that the risk of URTI increased as the number of children in the room decreased (OR = 0.620, 95% CI = 0.411–0.935).

The risk of LRTI increased as the household size decreased (OR = 0.213, 95% CI = 0.048–0.937) and it was higher if the child had no siblings (OR = 7.831, 95% CI = 1.065–57.578).

3.4.3 Risk factors for gastroenteritis in child day care (Netherlands)

This was a prospective cohort study involving 100 childcare centres and 1,600 children during 2011–2013[186]. It is included in this section because it assessed crowding and centre population size as having potential influence on GE rates in childcare, in addition to hygiene and staff-related factors. Children were reported as ill either by childcare centre staff if the child became ill at the centre, or by their respective parents/caregivers. The study defined an episode of GE as an acute onset of three or more episodes of watery stools per day or an acute onset of three or more episodes of vomiting per day. A child had to be fully recovered for at least seven days before being reported ill again. The study assessed crowding as the percentage of maximum legal occupancy for the whole of the childcare centre. In the Netherlands, the requirements for the space and furnishing and fittings of childcare centres differ from one municipality to another. Floor area per child was not directly measured in the study.

The study found that for each percent increase in crowding rate of the childcare environment, the GE incidence increased by 0.7% (RR 1.007, 95% CI 1.003–1.011). The study also found a small but significant effect for centre population size, in that for each additional child enrolled for day care, the GE incidence increased by 0.1% (RR 1.001, 95% CI 1.000–1.003) [132].

3.4.4 Health in day-care centres study (SIB) and subsequent ventilation study (Denmark)

The Danish ‘Health in Day-care Centres’ (SIB) study aimed to determine the factors responsible for the spread of infectious diseases among children in Danish nurseries and kindergartens, during the period 2010 to 2013 [168]. The study included investigation of viral and bacterial environmental loading, and a hygiene intervention study. As part of the SIB project, 20 childcare centres from the municipality of Copenhagen participated in a study in winter 2012. Child sick leave related to 12 illness categories was recorded on sick leave registration sheets filled out by childcare teachers, for 635 children over an 11-week period. The sick leave registration sheets were used for one year in winter 2013, and were then related to results from a ventilation study by Kolarik et al.

The ventilation study used three proxy measurements for ventilation:

i) exchange rate measured with the decay method
ii) exchange rate measured by the perfluorocarbon tracer gas (PFT) method
iii) CO_2 concentration measured over a 1-week period.

The highest number of sick days was recorded in centres with the lowest exchange rate, and the study found a 12% (95% CI 2–21%) decrease in sick leave days for each per-hour increase in exchange rate, when the exchange rate was measured with the decay method. No statistically significant effect was found for exchange rates measured with the other two methods, however. The CO_2 rates were described as ‘unexpectedly low’, with an overall mean concentration of 634ppm, and mean concentrations over 1,000ppm found in only one centre. Exchange rates differed between the childcare centres and also between the methods used to measure the air change rates. The authors suggested a number of reasons for variations in the results by method, including measurements by different researchers for each method, and difficulties of operation in the childcare setting. The authors commented that the decay method can be considered as a measurement of building airtightness, while the PFT method responds to a combination of airtightness and human behaviour. They regarded the decay method as likely to be the most accurate when applied in the manner used in the study.

Another limitation of the study was the one-year gap between illness data and environment data. The paper by Kolarik et al. did not give a breakdown of infections, only the relationship to sick leave days, but the result does suggest that ventilation rates have an effect on child illness rates. The relationship between air quality and ventilation is also related to occupancy rates, suggesting that crowding can also have an effect if ventilation is not increased in response to increased occupancy.

3.4.5 The IECH study (Denmark)

The Danish research programme ‘Indoor Environment and Children’s Health’ (IECH) was conducted between 2007 and 2010 in or near the city of Odense, Denmark [187]. The study examined associations between indoor environmental factors in homes and kindergartens, and children’s health, with special emphasis on asthma and allergy. The study had two stages, with a third proposed. In the first stage, a 116-question survey of child health was distributed to 17,000 families with children aged one to five years, eliciting 11,082 returns (63.4%). The second stage was a case-base study of 500 children from the stage one cohort, involving an in-depth study of 500 children, 500 homes and 151 childcare centres. The selected children included 200 children (cases) symptomatic for at least two of three diseases categorised as asthma, rhinoconjunctivitis, and atopic eczema, and 300 randomly selected children (base group) [187]. A third stage was proposed as an intervention study involving renovation of three to five of the kindergartens with the highest absenteeism rates among the children, to improve the indoor environment [188].

The second stage of the study was extremely thorough in its data-gathering, measuring temperature, relative humidity (RH), CO_2 (for inference of ventilation rates), and a wide range of home indoor air contaminants including allergens, phthalate esters, polyaromatic hydrocarbons (PAHs), squalene, cholesterol, and fungi. Household characteristic were also described including floor coverings, ventilation systems and evidence of visible mould or dampness. For childcare centres, sampling included CO_2, temperature, RH, ultrafine particles, fungi, and occupant density. In addition to health questionnaire data, child health measures included biometrics, blood samples for IgE measurement, and urine samples for analysis of phthalate metabolites. Child absence days were recorded for childcare attendance.

The literature search found 13 papers published in English from stages 1 and 2 of the study, but no published papers for the third stage. While the study included childcare settings, environmental conditions and health outcomes, the papers published in English from the study mainly concerned home environments rather than childcare, and chemical contaminants as aspects of air quality rather than infection rates.

The study found no clear association between childcare CO_2 level and illness, or childcare crowding and illness. The indoor spaces were described as ranging from 4.9m^2 to 18m^2 per child. This density is much less than the 2.5m^2 per child New Zealand minimum standard, but the paper did not indicate whether this was activity space or total building space. 83% of the children were exposed to an average temperature in the interval 20–24^{o}C (Clausen, 2009). Average relative humidity ranged from 22% to 48%.
Unfortunately, the one paper describing childcare findings did not describe the measures used to identify reasons for child absence.

3.4.6 Significance of playroom area for illness among children in day care centres (Denmark)

Sick leave among the children in 24 day nurseries in Copenhagen was registered during two periods of one year each "with a five year interval" [146, 147]. The physical, environmental and hygienic conditions of the institutions were assessed by means of interviews and inspection, supplemented by information from the local authorities. The first year's data indicated that sick leave constituted 7.5% of the days during which the institutions were open and the average number of sick days per child varied from 14.6 to 24.4. After the second data-gathering period, a statistically significant correlation was found between the playroom area per child and absence due to sickness in that, after correction for the influence of age in a multivariate analysis, sickness will decrease 10.8% for every square metre increase in playroom area per child.

Unfortunately, only the abstracts for these studies were available in English. No details were available for data-gathering methods, and the space per child was not given in either abstract.

3.4.7 Oslo study – Respiratory health and day care centre characteristics (Norway)

This study linked health effect data from a 1996 survey among three to five year old Oslo children with descriptive information of childcare centre characteristics from inspection of 175 childcare centres by an engineer during the same period [189]. The aim of the study was to estimate associations between dampness problems and other building characteristics and several respiratory health outcomes. The study used a questionnaire distributed to parents to obtain data on childcare arrangements, children's health, environmental conditions, and family characteristics. The questionnaire collected retrospective data on children's illnesses during the previous 12 months. Each of the 175 childcare centres was assessed for size of childcare population, hygiene, building age, roof shape, building material, type of ventilation, dampness problems, and smoking indoors in the childcare centre. The study found no association between any of the building characteristics and child health, but air exchange rates were not measured.

The study had a number of limitations, including a lack of data for ventilation type and use of 12-month parent recall. The study recorded attendance numbers, but no data on numbers of children per room or per m^2. The authors noted that the methodological challenges in studying health effects of the childcare environment should not be underestimated.

3.4.8 Helsinki-1 study – Day care and home variables and child illnesses (Finland)

A prospective study undertaken in 1985–86 provided an analysis of outcomes and exposures for 1,108 children attending 27 childcare centres [107]. The study recorded area, volume, group size and ventilation system data for the childcare centres, as well as child illness data for a four-month period from September to December 1986, as well as home occupancy data, household income and exposure to tobacco smoke. The age range in this study was zero to eleven years. The inclusion of children as old as eleven in 'day care' suggests that the study included what would be described in New Zealand as after-school care, or possibly weekend care, but the authors did not provide a definition of 'day care'. The conclusions distinguished children under three years old from children over three years old as groups, and the tables of results for illness rates were given by age. The total number of children at the centres ranged from 24 to 138 (average 30.9) for children over three years. Total numbers of children in groups ranged from two to eight.

Data were collected on episodes of any illness requiring absence from childcare. The authors stated that criteria for excluding children from the childcare centres due to various infectious diseases, and for their re-admittance, are regulated uniformly in Finland according to instructions issued by the Medical Board of Health. Information on daily absences and diagnoses was collected from parents by the qualified children's nurses or nursery school teachers responsible for each group of children. Diagnostic grouping based on the reported diagnosis made by the physician was obtained from the parents immediately after each period of sickness. Home information was obtained by questionnaire.

Children under the age of one year had as many as 11 illnesses per follow-up year. Children under the age of three years had an average of 7.9 periods of illness per follow-up year, and older children 3.8 periods of illness. Average duration of illness was longer in younger children. Children under three years had an average 39 days of illness, while older children had an average 17 days of illness.

Regression analysis showed an association between morbidity and the following parameters: total number of children, floor area, separate facilities for different groups of children, fully mechanised ventilation in the childcare centre, and the total area of the child's home. Passive smoking, number of siblings, number of household members and incomes of families were not significantly associated with morbidity.

For children under three years of age, a smaller area and volume of childcare centres and lack of fully mechanised ventilation were significantly associated with a higher incidence of one or all of the six most common infections. The most common infections were URTI (46%), diarrhoea (17.2%), otitis media (12.9%), eye infections (4.0%), acute tonsillitis (3.2%) and bronchitis (3.0%). A smaller area per child was correlated with a higher incidence of bronchitis among children under three years of age ($r = –0.12$, $P = 0.03$).

Mean space per child in childcare was recorded as 8.3 (4.6–15.9) m^2 per child for children under three years, and 6.2 (2.2–10.4) m^2 per child, for children over three. The calculation of space was not defined, but Finnish requirements at the time were well in excess of New

Zealand regulations, at 6.0m^2 per child over three years old, and a recommendation for 8.5m^2 per child under three years [107].

Having a large number of children in childcare was associated with a high incidence of one or all of the most common infections among both younger and older children. A larger total number of children at a childcare centre was correlated with high incidences of tonsillitis ($r = 0.10$, $P = 0.005$), diarrhoea ($r = 0.12$, $P = 0.001$), and the total number of indicator illnesses ($r = 0.09$, $P = 0.01$) among older children.

The study provides a comparison for categorised illness rates and observations related to crowding, but the study did not take into account temperature or relative humidity.

3.4.9 Temperature and illness outcome study (Germany)

A 1985 article by Wirsing, Passauer, and Brecht is relevant to this section, but this article was in German with only the abstracts in English. The authors reported a significant correlation between nursery indoor temperatures and acute respiratory disease (ARD). Low temperatures were associated with increased ARD. The authors suggested that "[there is] only a small sphere of comfort-climate for young children with room temperatures between 18°C and 24°C" [190].

In a later article, Passauer and Wirsing [191] also described low floor-level temperatures in German childcare centres. The surface temperature of the floor during the heating season did not reach the desired range of 20°C to 22°C. 59% of the measured minimal values, 39% of the mean values, and 18% of the maximal ones were about 15°C, "or even drastically lower." Of the air temperature in the near-floor zone (at a level between 0.15m and 0.50m), 31% of their minimal values at the level of 0.15m and 27% of their minimal values at the level of 0.50m were below 16°C.

3.5 Cost of ECE or childcare-attributable illnesses

The financial cost of early childhood education and care attendance is included in this review, as measures of these costs will support or counter the need for interventions.

In a Memphis study in 1984–85, the mean monthly cost of medical care was $32.94 for children in the "highest risk settings" compared with $19.78 for those in other settings. In that study child illness accounted for 40% of parental absenteeism from work, and the mean number of days lost per month was 0.52 for parents of children in childcare centres, compared with 0.37 for those of children in other forms of full-time care outside the home [142]. The authors found that there are potentially modifiable childcare risk factors for illness resulting in excess financial costs, but also noted that financial data presented in their study pertain to families in Memphis, Tennessee enrolled in a prepaid health plan.

The economic consequences of illnesses among children in childcare centres were estimated in Helsinki during a one-year period, 1985–1986. The municipal childcare centres took care of 14,882 children at the end of 1985. A questionnaire was sent to the parents of children in eight municipal childcare centres to ascertain how often a guardian had to stay away from work when a child became ill; how often a visit to a physician was necessary; and how often paid care for the child was needed. The questionnaire was filled out in a series of 180 consecutive periods of absence, immediately after each period. During this one year of the prospective study there were 9,289 periods of absence due to illness among childcare centre children, or 4.9 periods of absence per year. The mean number of days of illness was 22.9 per year: 39.3 for children under the age of three years and 17.0 days for older children. The mean period for childcare centre care per child was 246 days in 1985. In 1990 dollar terms, the total loss due to illnesses among all childcare centre children was estimated to be US$22,485,000 [192].

In 1999 the New Zealand cost of infections attributable to early childhood centre attendance was estimated at NZ$20–50 million per year, which for 143,540 enrolled children is approximately NZ$140 to NZ$350 per child. The estimate was conservative, and data from the United States indicated that gastrointestinal infections alone could potentially be costing NZ$20 million per year in 1999 terms [11].

A 2010 Australian study used a societal perspective to assess the economic impact of influenza-like illness (ILI) on families with children attending childcare. Costing calculations included health care visits and hospitalisations, medication costs, related travel costs, and parent time lost (time that would have otherwise been spent on another activity including work), and secondary illness cost. Parents lost on average 13 hours of work and 3 hours of leisure time per ILI. The mean cost of all ILIs was AU$626 (95% confidence interval: AU$484–768) per ILI, with no significant differences observed between viruses. They concluded that for families with a child attending childcare, ILIs cause a substantial economic burden. An ILI in a child with working parents and/or with longer duration appeared to cost more in monetary terms [193]. Enserink et al. estimated the additional costs related to care and treatment of GE and ILI episodes standardised for the Dutch community in 2012. The additional community costs in 2012 for GE and ILI episodes related to childcare centre attendance were estimated at €25 million and €72 million respectively [109].

Kolarik et al. referred to a Danish study by Pedersen published in Danish in 2007 that estimated that a reduction of one child sick leave day per year would be equivalent to a surplus of DKK445 million (approximately US$81.5 million) [168]. It is difficult to compare these cost estimates, as they are based on different illness groupings and different cost components, but they do indicate that the financial cost of childcare-attributable illness can be substantial.

3.6 Research in childcare settings

In their systematic review of child day-care attendance and acute infectious diseases, Sangrador et al. [110] noted that there was a great variation in assessed diseases and measures of effect in the studies they reviewed. Very few papers used the same infection criteria. They recommended that new studies that analyse the magnitude of the risk of childcare centre attendance should use prospective designs, in which the measurement of exposure is as accurate as possible, using various graduation parameters such as starting age, hours, and days. They also recommended that disease events should be measured by both “quantitative (incidence, incidence density) and qualitative (frequent episodes) and multivariate adjustments” (from a Google Translate version).

Söderström [194] has observed that carrying out studies in childcare centres is challenging. Many parents are too busy to participate; they may be critical of studies; and some want to protect their identity. They mentioned that a Danish research group had invited the parents of 2,160 children from 36 childcare centres to take part and only 179 (8%) agreed, despite being invited by the Statens Serum Institute, which had a well-established reputation with the public for being engaged in important issues related to infectious diseases.

3.7 Summary

3.7.1 Two-component review findings (Part One)

General infection risks associated with childcare

Centre-based childcare presents a substantial increased risk of illness frequency for a range of infections and conditions, including respiratory infections, asthma, ear infections and gastrointestinal infections. There is an independent risk of ear infections as sequelae to upper respiratory tract infections. The risks for 'home-based' or 'family day care', with group sizes of 12 or less, are lower and may be comparable to care at the child's own home.

The greatest risks for morbidity by age arise from attendance in the first two to two and a half years of life, and especially in the first year, and especially for respiratory and ear infections, but exposure during this time is likely to result in fewer illnesses during subsequent childcare, and possibly into early school years. The increased risks associated with day-care centre rather than home-based care were greatest for children under one year old.

Crowding and group size

Infection risk associated with crowding in childcare environments is summarised in Section 3.3.1, with four out of five studies indicating that increased area per child is associated with reduced illness. Crowding has been shown to be a risk for infections in housing, suggesting that this may also be the case for childcare. Some studies have found that, consistent with lower morbidity in home-based care, group size is positively correlated with illness rates, with one study finding group size to be more important as a risk factor than floor area per child. The findings were not consistent across different articles, however, with one study finding that smaller group size was associated with higher morbidity.

Temperature and humidity

There is a well-established relationship between viral survival and temperature, with cooler temperatures favouring viral survival. This relationship applies across a broad range of normal environmental temperatures, from low single-digit temperatures to mid-thirties (^{o}C).
The relationship between viral survival and either relative or absolute humidity is more complex, with some viruses surviving better at low relative humidity, and others favouring higher relative humidity. Lipid encapsulation of viruses is a key factor in the effect of humidity on viral survival, with encapsulated viruses demonstrating better survival at lower rather than mid-to-high relative humidity. Some viruses have a U-shaped response to relative humidity, with both low and high humidity, as well as immersion, favouring survival. Lower temperatures will generally favour viral survival, but surface moisture from children's activities and wet cleaning of surfaces in moderate to high humidity conditions may also contribute to viral survival and transmission.

Host chilling also increases susceptibility to infection, and cooler temperatures (below $12^{o}C$) can have an adverse effect on lung function.

Bacterial and viral environmental loading and transmission

There is evidence that bacterial and viral loading, particularly of microorganisms and enterotoxins of human origin, can be greater in childcare environments (up to 57 times higher) than in the outdoor environment. Both aerosol and surface contamination are risks for infection transfer.

Air quality

An association has been demonstrated between low airflow rates, high CO_2 levels, and concentrations of airborne bacteria. Higher CO_2 levels have also been associated with wheezing. Stratification may also be a risk in rooms with little air movement, such as sleep rooms, by the trapping of exhaled organisms in the lower airspace.

Air pollutants such as diesel exhaust are associated with respiratory tract illness and inflammation, and chronic inflammatory processes. Higher carbon monoxide levels and particulate levels (PM_{10} and $PM_{2.5}$) in urban childcare centres compared with rural childcare have been associated with coughs and wheezing. Polyaromatic hydrocarbons have been associated with respiratory illness and bronchitis, especially in preschool children. These findings suggest that proximity of childcare environments to air pollution sources, such as heavy traffic, may increase risk of respiratory illness.

Volatile organic compounds that may arise from non-traffic sources such as building finishings and cleaning agents, are associated with wheezing in preschool children, and have been found at levels exceeding national guidelines in childcare centres.

Microbiological air-quality issues in childcare settings identified in the review included an association between both fungal concentrations and house dust mite allergen (Der p1/g dust), and wheezing.

Several studies have shown that children can experience adverse health from exposure to air pollutant levels below regulatory guideline levels.

3.7.2 Three-component review findings (Part Two)

Few studies found in the review combined all three components of the literature search (environmental conditions, childcare as the setting, and illness rates as outcomes).
The papers for the Portuguese study by Alexandrino et al., the Dutch study by Enserink, the IECH study, Helsinki I, and the Danish study by Rindel et al. reported directly on crowding. Enserink et al., Alexandrino et al., Nafstad et al. and Rindel et al. reported a positive association between crowding and infection rates. The IECH study found no clear relationship between these parameters. Nafstad et al. also found a positive correlation between total numbers of children in a childcare group and infection rates, but Alexandrino et al. found the opposite: an increase in infections as group size decreased.

The Portuguese ENVIRH study did not report directly on crowding, but found a weak association between CO_2 levels and wheezing, and for that study, Mendes et al. suggested an association between CO_2 levels, crowding and poor ventilation. Papers from three studies (ENVIRH, IECH, and the German study) reported results in relation to temperature and humidity. Neither the ENVIRH nor the IECH study found a significant relationship between temperature or RH and illness, but these environments were in a narrow temperature range and all above WHO recommendations. The abstracts from the German study did report a relationship with floor-level temperature and acute respiratory disease, however, and environments in this study included some with temperatures below 16^{o}C.

Other issues in childcare settings identified in these studies included association between TVOC levels, fungal concentrations and house dust mite allergen (Der p1/g dust) and wheezing.

Not all studies reported on individual infections. The studies in Denmark reported conditions in relation to absence rates only. Only the study by Enserink et al. and the Helsinki 1 study reported on enteric infections. The ENVIRH study, the Danish studies and the Norwegian studies used retrospective illness or absence data.

3.7.3 Implications for further research

The review supported the need for further research into crowding, humidity and temperature in relation to illness, but did not assist with methodology for environmental data or illness data collection. The review indicates that centre conditions such as ventilation, hygiene and sick child exclusion should be taken into account, as well as child age, early age of attendance and home conditions.

The review showed a lack of comparable studies with similar methodologies, and revealed little information regarding data collection methods (paper form, phone or person-person interview, website).

4 Methodology

4.1 Overview

Chapter 4 describes the hypothesis for this thesis, along with considerations of choice of study population and geographic area, potential data sources, and the options for research methods. Chapter 5 describes the methods used for the resulting prospective observational cohort study. The proposed study, called the Early Childhood Education Environments study (ECEE), was an investigation of environmental conditions and illness outcomes in childcare, in line with the aims and hypotheses described in Chapter 1:

Hypotheses

1. Crowding in childcare centres is associated with increased rates of child illness, child absence from childcare, and parental absence from work.

2. Low indoor temperatures (below 18°C) in childcare centres are associated with increased rates of child illness, child absence from childcare, and parental absence from work.

3. There is an association between indoor humidity and rates of child illness, child absence from childcare, and parental absence from work.

To test these hypotheses, data were needed for the following exposures and outcomes.

Exposures

- Indoor population density in childcare centres
- Temperature and humidity in childcare centres
- Other childcare conditions affecting disease rates such as hygiene practices
- Home environment conditions such as heating

Outcomes

- Child days sick and days of absence from childcare
- Child infectious disease illness rates
- Parental absence from work associated with child illness

Related information on heating and ventilation systems and practice

Conditions in childcare centres will be influenced by the heating and ventilation systems available, and their use, so it was considered useful for the study to collect data on:

- Heating systems including type, location, and perceived effectiveness
- Teacher-reported use of ventilation systems
- CO_2 levels, especially in sleep rooms (which, in contrast to activity spaces, are often not directly connected to an outdoor space)

Research framework

The literature review did not reveal any existing models for research in ECE and care settings, and as described in Section 4.2, no data or data collection programme existed in New Zealand for indoor environmental measures or children's illness rates. This meant that environmental measurement would need to be prospective, and that being the case, it would be most sensible to use a prospective cohort framework for illness data collection within the same time period. The prospective approach had advantages over retrospective data collection for illnesses, as prospective studies help to reduce recall bias [195].

This study design could not directly ascribe causation, so results would need to be considered in the light of other research (for example, known risks or infection transmission mechanisms) for any plausibility of inferred causation.

The design of the study also needed to take into account the sociological context. Important considerations were:

- Time pressure on centre managers and teachers, as well as time and work demands for parents
- Risk to the reputation of the participating childcare centres
- Events that might occur for children or parents during the course of the study, including serious health issues or domestic / relationship events.

4.2 Data sources

4.2.1 Existing data sources

In New Zealand, early childhood education services are licensed according to combined measurements of indoor space, outdoor space, and numbers of teaching staff, but no database exists of indoor space measurements. Licensing cannot be used as a proxy for indoor space for two reasons. Firstly, a centre could be operating at more or less than its maximum licensed capacity. Secondly, licence capacity is based on the minimum space available either outdoors or indoors, and set at whichever is the smallest. For example, a centre that would comply with minimum space for 40 children indoors might only have minimum space for 30 children outdoors, in which case it would be licensed for 30 children. Indoor temperature and air-quality data were not available from any existing source, as they are not measured by either the Ministry of Education or Public Health Units.

The Ministry of Education collects daily attendance data from every ECE Service, so this was available for the study. Meteorological data were available from the New Zealand Meteorological Service.

New Zealand has no systematic recording of common respiratory infections such as colds, and most gastrointestinal infections are not recorded unless they result in hospitalisation, are notifiable, or are part of an outbreak recognised by a Public Health Unit. While early childhood education services have data for children’s absences due to illness, there is no common recording system in use, no national data collection system, and the service’s 'system' may be a notebook or diary. Some data related to outbreaks of notifiable infectious diseases are collected by the Institute of Environmental Science and Research (ESR), but this data-collection process relies first on infected children visiting a local doctor or a hospital, and secondly on the doctor completing the notification process. Most of the infections of interest in this study, especially respiratory, ear and eye infections, are not notifiable, and are therefore not part of any systematic data-gathering (see Appendix 3: New Zealand Schedule of Notifiable Diseases).

4.2.2 Available data collection systems, safety, and security

Environmental measurements

The Education (Early Childhood Education Services) Regulations 2008 set a minimum temperature of 16°C, measured between 0.5m and 1.0m above the floor. Taking measurements in this zone represents the experience of children under five years old for much of the day (sitting on chairs or standing) and means that the results of temperature measurements are directly relevant to current regulations. This height range also means that the measurement devices are likely to be accessible to children. The safety of these devices was a consideration in the choice of measurement system, along with accuracy, reliability, and the cost or availability of equipment.

Options considered for temperature and humidity were HOBO data loggers, 'i-buttons', and Wireless Tags. HOBO loggers and i-buttons had been used successfully in previous temperature monitoring by the University of Otago, while the Wireless Tags had been used successfully by Building Research New Zealand (BRANZ). The disadvantage of the i-buttons was that they could not be securely attached to a wall, and at 16mm in diameter were small enough for a child to swallow. The HOBO data loggers were much larger and could be safely secured to a wall, but were expensive compared with the Wireless Tag system. At the time the project was being planned, most of the University of Otago's HOBO data loggers were already committed to another research project for the period of the ECEE study data collection phase, so the use of HOBOs would require purchase of more devices. The Wireless Tags were 41mm square, which made it conceivably possible (although difficult) for a child to swallow or choke on a Tag. They could, however, be screwed securely to a wall. The Wireless Tag system had the advantage of providing real-time data, including Tag movement data and battery status, enabling continuous monitoring of the system. It had the disadvantage of relying on wireless networks via the internet. The physical security of the Wireless Tag system, real-time monitoring, and considerably lower total system cost than HOBOs made it the preferred system for this research.

The Wireless Tags were not available with CO_2 monitoring, so for peak measurements of CO_2 in sleep rooms, which were the areas of most concern in relation to ventilation, a HOBO monitor was considered the best available option.

Wireless Tag Managers and internet security

In the original protocol for the ECEE study, the Tag Managers (devices that collect Tag signals and then communicate that data to the internet via a router) were to be connected to the internet via the childcare centre routers, unless there were no spare ports available.

The Wireless Tags and Tag Managers are an Internet of Things (IoT) system. While the data collected by the Tags would be of little or no value to anyone outside the study, connection to the internet could compromise an associated system, for example computers connected through a shared router. As the Tag Managers both send to and receive data from the internet, University of Otago Internet Security identified a risk to the childcare centre systems via the Tag Managers. The risk to confidential information held in ECE centre systems was considered too great to allow direct connection, prompting the need for independent routers to isolate the Tag Managers from any other system.

4.3 Study population and recruitment

4.3.1 Population factors considered in study design

The study design needed to consider:

1. The total number of children needed for adequate study power
2. The age range of the children to be eligible as study participants
3. Variations in total population and climatic conditions across the Wellington region

4. Variations in childcare centres, including hours of operation and ethnicity of the children

4.3.2 Power calculation and cohort size

Sample size would ideally be calculated using previous studies to estimate likely effects of environmental conditions, and would take into account clustering by childcare centre (for analysis by generalised linear mixed model (GLMM)), but there were very few equivalent studies from which to gauge the effects of crowding in childcare, or other environmental conditions on health (see Section 3.4). Our initial knowledge was insufficient for power calculations for a GLMM, as important variables such as the inter-cluster correlation coefficient of childcare absence were unknown, and most parameters needed were only guessable within a wide plausible range. An experienced statistician (Dr Nevil Pierse) was asked to provide expert guidance as to an appropriate model to use. He suggested using a simple t-test as a base model of calculations.

Model assumptions were:

$\alpha = 0.05$

$\delta = 1$

$\sigma = 3$

$M = 1$

power $= 0.8$

This simple t-test model suggested a study size with 142 exposed children and 142 control children. If the true difference in the experimental and control means was 1, the study would need 142 experimental subjects and 142 control subjects to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05. Given the simplification in the model and the uncertainty about the assumptions, we decide to accept a minimum target sample size (after attrition) of about 300 children to achieve 80% power.

Note that while this was a calculation for a case-control study, the study design was prospective cohort. The case-control power calculation was as approximation, and would work for an even split around a threshold, e.g. above or below 18^{o}C, as was the case, but not so well if the split was very uneven.

The enrolment target was also difficult to estimate, as there were no New Zealand ECE sector environmental or epidemiological studies for precedent, and studies in other countries had enrolment or participation rates ranging from 8% to 63% [187, 194]. The study needed to allow for loss of participants during the study, especially due to change of location or loss of engagement from parents. The study also needed a variety of centres to provide a range of environmental conditions. Taking into account potential attrition and estimates of follow-up time demands for communication with parents / caregivers (phone and text), a minimum starting cohort of 400 children and a maximum starting cohort of 600 children was used to derive enrolment targets. Allowing for an optimistic 75% maximum enrolment rate, a target pool of 800 children was set for distribution of enrolments forms. To achieve this number, it was estimated that the study would need to have about 25 childcare centres enrolled, depending on centre size and whether centres with multiple spaces engaged with the study.

4.3.3 Child cohort age range and exclusions

New Zealand early childhood education and care services enrol children from as young as a few weeks old, and normally up to five years old. A relatively small number of children attend up to six years old, beyond which they are legally required to attend school, but most children start school at five years old. The licensing of centres has a division at two years of age, including different ratios of children to teachers, and different rates of government funding per child. For these reasons, as well as for developmental, behavioural and safety reasons, it is common for childcare centres to have separate spaces for children under two years old, or to limit enrolments to children over two years of age. It is not universal, however, and some ECE centres have 'mixed-age' spaces combining infants, toddlers and other preschool children in the same space.

Some studies have shown that when infants and toddlers in childcare are in the same activity space as older children, older children have increased infection rates, and that faecal contamination is higher in infant and toddler dedicated areas than in dedicated areas for older children [107, 196]. Another study found that centres which accepted children less than two years of age had a 3.55-fold higher incidence of diarrhoea compared with centres that did not [182]. If the study had included spaces for children under two years of age, there would have been an increased risk of infection in some centres compared with others due to age mixing. For this reason (to reduce the number of extraneous variables), children under two years old were excluded from the study, and environments that normally included children under two years old were excluded from the study. This is consistent with Pönkä et al., who also excluded from their study centres that did not provide separated spaces for children under and over two years of age [107].

Attendance at an ECE centre that was not part of the study would have interfered with attribution of illness to ECE centre conditions, so children who attended more than one service were excluded.

A limit of one child per household was applied to prevent double-counting of parental lost work time, which could occur if two children from the same household and childcare centre were off sick at the same time. The selection of the youngest child made it more likely they would remain enrolled for the full duration of the study.

4.3.4 Variations in ECE hours and ethnicity

ECE centres included in the study were limited to those operating at least eight hours per day. This limitation did not prevent children being enrolled at those centres for fewer than eight hours per day, however, and it was expected that some would attend less than five days per week.

In New Zealand, full-day attendance is most likely in the categories of Education and Care, Kōhanga Reo, Home-based and Hospital-based categories (see Chapter 2 for categories of New Zealand ECE centres). Home-based and hospital care typically involve small numbers of children at a time, and the hospital setting may involve other health factors not typical of the general population. Kōhanga Reo (which translates as ‘language nests’) can have similar building and crowding characteristics to childcare facilities, but have an atypical ethnic distribution. For example, in 2017, 94.6% of children enrolled in Kōhanga Reo were of Māori ethnicity, compared with 20.7% in Education and Care Services and 23.3% across all early childhood education services [20].

For these reasons the cohort was limited to the Education and Care category. Within this grouping, other centres aimed at specific ethnic groups, such as Pasifika centres, were excluded.

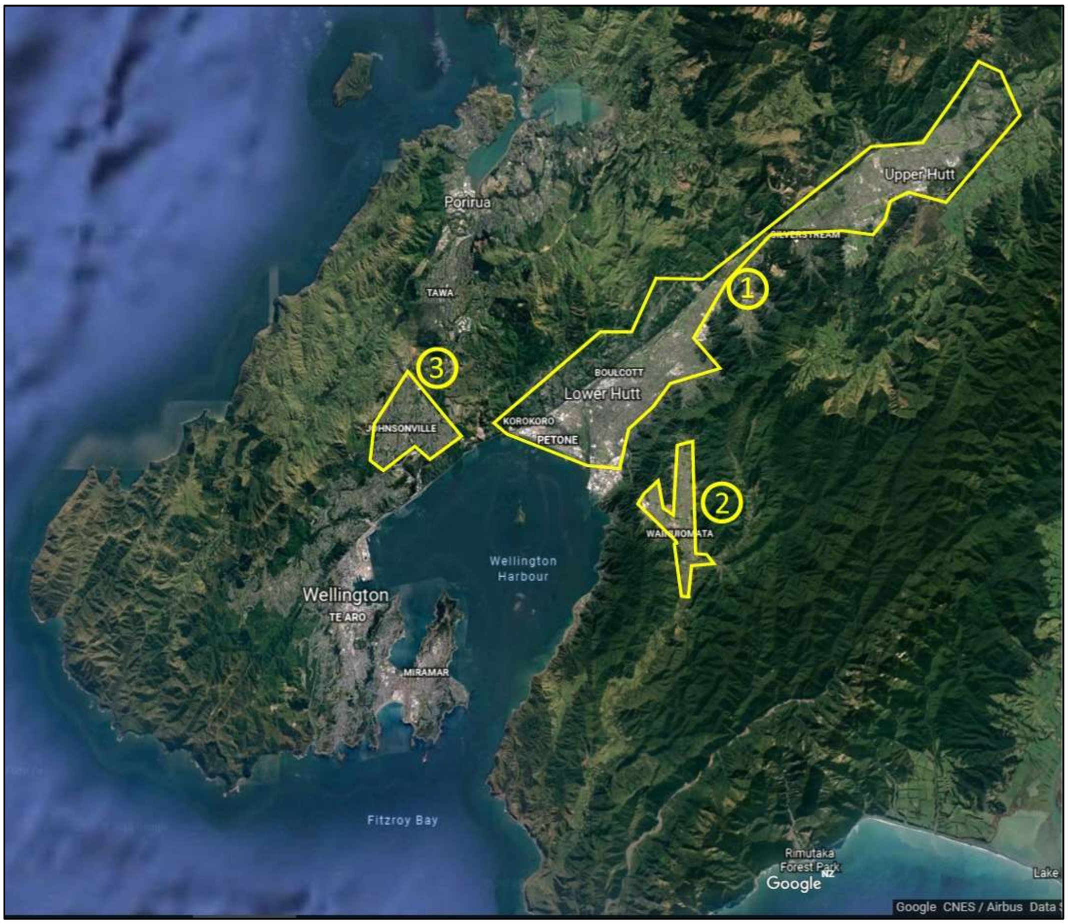
4.3.5 Cohort geographic area selection

The complex topography of the Wellington region, combined with the concentrated air flow through Cook Strait, generates a range of microclimates within the region (see Appendix 4: Examples of Climate Variations in Wellington Regional Suburbs). Wellington harbour and Cook Strait have a moderating effect on Wellington city temperatures in comparison to those suburbs further from the sea, while topography has a major effect on wind speed. The weather station at Wellington Airport, on the southern coast of Wellington, has recorded the highest average annual wind speeds of the region's weather stations at 25.8 km/h, while the Wallaceville weather station in the upper third of the Hutt Valley has recorded the lowest average at 13.8 km/h. Wellington City has the least extremes of temperature (lower maxima, higher minima) than areas in the region further from sea [197].

Central Wellington, and Wellington City as a whole, have different socio-economic profiles to the outer suburbs and bordering municipalities. For example, for people aged 15 years and over, the 2013 median income for Wellington City was $39,900, while for Lower Hutt City it was $31,500 [198]. ECE centres in some central Wellington suburbs may reflect this difference, but ECE centres located in the central business district (CBD) and along commuter routes may have a demographic profile reflecting a mix of populations, as the centre may be chosen for its commuting convenience or proximity to a workplace. ECE centres in the CBD may also be in locations with very different building structures and traffic density compared with outer suburbs.

Taking these factors together, the first preference for geographic location was the Hutt Valley (Figure 19;1), as it presented the least climatic and demographic difference between ECE centres. Second preference was given to the suburbs of Wainuiomata (Figure 19;2), and to Johnsonville and Newlands (Figure 19;3). These suburbs are predominantly middle- and lower-income areas with income distributions lower than the Wellington City median [198].

Figure 19: Study geographic boundaries – Hutt Valley, Wainuiomata and Johnsonville-Newlands



Wainuiomata has a valley climate, and is 20km from Cook Strait and between 2km and 4km distant from Wellington Harbour, making its climate more like that of the Hutt Valley than Wellington City. Johnsonville and Newlands have higher average wind speeds than the Hutt Valley, but some separation from the harbour (1km to 4km) makes their climate a little more like that of the Hutt Valley than is the case for some other Wellington suburbs.

4.3.6 Recruitment

The ECEE study required enrolment of ECE centres for environmental measurements as well as recruitment of children for illness data from the same ECE centres. For this reason, recruitment was undertaken through the enrolled ECE centres.

4.4 Māori consultation

Māori participation for children over two years old in the general category of Education and Care is approximately 21% in the Hutt Valley [17], so the study was of relevance to Māori. Tereasa Olsen, Manager, Health and Social Services at Kōkiri Marae in Seaview, Lower Hutt, was approached for assistance with appropriate methods and tikanga Māori (Māori culture and practices). Kōkiri Marae has been actively involved in health and social services for Māori, including major roles in establishing and supporting the development of other organisations such as Tu Kotahi Māori Asthma Society, Naku Enei Tamariki (Māori section), Mana Wahine, Te Ara Whanui Kura Kaupapa Māori, Paparakau Multi Cultural Society and Whai Oranga o Te Iwi Health Centre [199]. Tereasa was supportive of the research and provided a check on enrolment forms, participant information, website questionnaires and general methods in relation to Māori.

4.5 Illness and absence data collection options

The ECEE study needed to collect continuous illness data from the parents of up to 600 children over a period of five months (see Section 4.3.2). Five options were considered for data collection:

1. Paper forms returned to the ECE centre and collected by the researcher
2. Paper forms returned to the ECE centre and posted
3. Paper forms posted by parents
4. Phone calls
5. Online website data entry by parents

4.5.1 Paper forms

Paper forms were seen to have major disadvantages, mainly related to the storage and retrieval of forms (weeks could elapse between illness episodes), and quality control. The filling of the form would not be the completion of the task. Parents would still need to remember to either post the form or take it to the childcare centre. Posted forms would also have required printed prepaid envelopes, which would have numbered in the thousands for direct return by parents, or would have presented the childcare centres with the extra task of posting sets of returned forms. Physical collection from childcare centres was not practical, as the childcare centres would be spread over an area with a driving circuit of at least 100km. Weekly collection would incur more than 2,000km travel in total and at least half a day per week, with follow-up for missing forms still required. Postal return would seriously disrupt the ability to check form completion. Paper forms would also present a time cost for data entry, and the potential for missed or illegible data.

4.5.2 Phone interviews

Phone interviews were preferred to paper forms, as they remove the need for printing, postage or travel. Phone interviews provide direct contact with a researcher, and allow immediate clarification of any question. Information collected could be directly entered onto a database, reducing participant error. Phone interviews had the disadvantage of either:

1 needing to take place at a pre-arranged time; or
2 interrupting a parent, possibly at an inconvenient time.

4.5.3 Website-based online data entry

An online method would require either an adaptation of an existing online questionnaire system, or the development of a new website and database, which could involve significant time and testing, and development costs. In addition, an online system would have potential risks from technology failure, either at the participant end (for example, internet connection failure or password problems), or at the data collection and storage end of the system.

Online data entry literature review and conclusions

To assist with evaluating the pros and cons of paper versus a website option, a literature review was conducted to look for experiences with similar research methods, and for information about best practice in online data collection. Full details of the literature review are provided in Appendix 5. The overall assessment of online data collection versus other methods was positive. Commonly reported advantages included better participant engagement, improved response times [200], and better quality of data, with less time and cost required for data collection [104, 201].

Participant engagement was reported to be as good or better than paper-based surveys [202-205]. Touvier et al.[206] commented that the web-based version of their survey was preferred by 92.2% of 128 users who completed the ‘satisfaction questionnaire’. Although the time needed to fill out the questionnaires was comparable for the paper-based and online versions, the web-based version was considered more satisfactory than the paper version. Among them, 18.8% declared that it helped them to detect a mistake and correct it. About 94.5% of the participants felt that the web-based interface was user-friendly, while 88.3% appreciated the ‘mid-questionnaire support message’. In a post-operative survey by Meier et al., the response rate increased from 68% to 78.8% three months after surgery, when a change was made from paper-based to online forms [202].

Traditional paper-based questionnaires may generate data entry mistakes along with missing, inconsistent or abnormal data [104, 206]. Kongsved et al.[203] stated that for the internet version of their study, 97.8% filled in a complete questionnaire without missing data, while 63.4% filled in a complete questionnaire for the paper-and-pencil version (risk difference 34.5%, $P < 0.001$). Web surveys allow for automated coding of survey results. This feature virtually eliminates the expenditure of time spent in processing completed surveys. It also significantly reduces the possibility of manual errors in the coding and data entry of survey responses [205, 207].

Key points for website-based data collection from the literature review

There were a number of observations from the online data collection literature review that were useful to guide the website-based data-gathering method, including:

- Employ multiple contact strategies, such as posters, pre-notices and articles in newsletters increase knowledge of, and interest in, the study [208].

- Use plain web pages set out clearly and not crowded with graphics or pop-ups that might cause confusion [208, 209].

- Choice of paging or scrolling format. The paging format allows the questionnaire designer to use more interactive features, while the scrolling format gives the respondent the opportunity to view the entire web questionnaire at once and therefore consider length [210].

- Although cookies are generally accepted for sites that a person needs to return to, there remains a concern about their use and potential breaches of confidentiality. Alessi et al. suggest that researchers should never use cookies without informing participants about it [211].

- Provide a non-automated alternative to internet-based communication may aid in participation [212].

4.5.4 Parent motivation and likely participation

The motivation of parents to participate in an online survey (or in fact any research) was discussed in a number of articles. Keusch [210] states that personal interest in a survey topic influences participation decision in cross-sectional web surveys, and that enduring involvement reflects an elevated state of care for an issue, product, or activity that is persistent over a long period of time. Singer [213] proposed a benefit-cost theory of survey participation. The argument was that people choose to act, in surveys as in life, when they perceive that the benefits of doing so outweigh the costs. Singer reports that in one experiment those who had said they would be willing to participate in a survey cited things like wanting their opinions to be heard or wanting to contribute to the research goals, or their interest in the topic of the survey or the incentive associated with participation. Keusch also comments that the felt legitimacy of organisations collecting survey data can affect participation [210].

Although the ECEE study could have expected participation based on care and interest, one difficulty in establishing cost-benefit for parents of preschool children is their time-limited involvement. In this study, involvement of the enrolled child in childcare following the data-collection phase of the study would be between zero and two and a half years, so for many parents their contribution would only benefit other children and parents in future years, requiring altruistic motivation or interest. The greatest likelihood of participation in the ECEE study seemed to be an appeal to interest and altruism, coupled with an assurance of ease of participation and very low time cost, and a legitimate organisational base (University of Otago and BRANZ).

4.5.5 Perceptions of confidentiality and anonymity

During the initial framing of the study, perceived confidentiality and the assurance of confidentiality were thought to be very important, and it was an important component of the ethics committee application. Assurances of anonymity (no person or centre identified in the results) were also thought to be important.

Singer [213] states that subjective perceptions of disclosure risk, in contrast with descriptions of objective risk, significantly reduce willingness to participate. Singer described an experiment in which people were invited to participate in a survey. The experiment showed that, at least for non-sensitive topics, excessive assurance of confidentiality could cause respondents to expect a greater risk to confidentiality. They were less willing to respond than when confidentiality was not mentioned, or mentioned, “as it were, only in passing.”

These views were considered in relation to the ECEE study, but there was also a concern that, while stressing confidentiality may reduce participation, there was a risk that a person concerned about confidentiality might dissuade others from participating if they lacked assurances. For this reason, assurances needed to be easily available, but not made a focus of attention.

4.6 Other factors potentially influencing illness outcomes

The study needed to allow for variables other than temperature, humidity and crowding in relation to children's illness outcomes. These included the child's health history, age and ethnicity, home environment, and childcare centre conditions.

Child history and health variables needed to include:

- Age and ethnicity
- Attendance at an ECE service before two years of age
- Recent overall health and history of illness
- History of asthma-related symptoms

Home variables relevant to the study needed to include:

- Household crowding, cold temperatures, dampness and mould
- Household income and Community Services Card use (as an indicator of low income)
- Other children in the house attending an ECE centre, or school

Childcare centre variables needed to include:

- Ages and numbers of children attending over two years old
- Natural and mechanical ventilation systems
- Dampness and mould
- Hygiene practices
- Sick child exclusion

Hygiene procedures are complex to assess, and advice on hygiene practices is inconsistent. For example, the Auckland Regional Public Health requires use of gloves for nappy change, but the Public Health offices of Wellington District and Canterbury District Health Board do not specifically advise use of gloves, due to a potential false sense of security, and risk of contamination of objects by gloved hands. Likewise, recommendations for use of bleach as a disinfectant vary from one Public Health office to another. A detailed assessment of hygiene practices was beyond the scope of the study, but the background data for the childcare centres could include some simple indicative questions, such as observed handwashing practice. Child health history, ethnicity, and home conditions could be obtained from the parents by questionnaire. Descriptions of childcare centre conditions could be obtained by direct observation during visits and by questionnaire.

4.7 Summary

The ECEE study was designed as a two-phase observational cohort study measuring crowding rates, temperature, humidity and CO_2 in childcare centres, with concurrent recording of children's absences due to illness and parental lost work time. The study also recorded some other variables that could affect illness outcomes, including brief health histories of enrolled children, home conditions, meteorological conditions, and childcare centre variables. Descriptive cohort data also allows future studies to compare cohorts. The data collection sources are summarised in Table 7.

Table 7: Data sources

<table>
<tr><th>Parameter</th><th>Data source</th></tr>
<tr><td colspan="2">Exposures</td></tr>
<tr><td rowspan="2">Crowding</td><td>Spatial measurements</td></tr>
<tr><td>Ministry of Education daily attendance data</td></tr>
<tr><td>Temperature</td><td rowspan="2">Wireless Tag monitoring</td></tr>
<tr><td>Humidity</td></tr>
<tr><td>CO_2</td><td>HOBO CO_2 monitor for peak sleep room measurements</td></tr>
<tr><td>ECE centre heating and ventilation systems</td><td rowspan="2">Management interview and researcher observation</td></tr>
<tr><td>ECE centre infection control systems</td></tr>
<tr><td>Home environmental conditions</td><td rowspan="2">Website questionnaire with phone assistance</td></tr>
<tr><td>Child health history</td></tr>
<tr><td colspan="2">Outcomes</td></tr>
<tr><td>Child illness</td><td rowspan="2">Website data entry by study participant</td></tr>
<tr><td>Parental lost work time</td></tr>
</table>

The study was geographically limited to the suburbs of the Hutt Valley, Wainuiomata, and the Wellington suburbs of Johnsonville and Newlands. The childcare centre sample was limited to full-day centres (open eight hours or more per day) with separation of spaces for children under two and over two years of age. The sample population was limited to children attending one early childhood service only, who were two years of age or older, and was limited to one child per family.

Website data collection was chosen for illnesses and child and parent absences, as well as for child and home background information. Wireless Tags with dedicated modems were chosen for temperature and humidity monitoring, while CO_2 was measured with HOBO monitors equipped with data loggers.

Background information for the childcare centres was collected on paper forms during on-site interviews. Attendance data was collected from the Ministry of Education ELI system and from childcare centre records, and combined with measurements of centre floor area (less fixtures and fittings) to obtain crowding rates.

5 ECEE Study Methods

The ECEE study had two main data collection phases:

Phase One Scoping, pre-testing, initial environmental measurements and background questionnaires (ECE centres only), November 2016 to May 2017

Phase Two Environmental monitoring and collection of attendance and illness data, from June to November 2017, which is winter to spring in New Zealand

Note: In this section 'parent(s)' includes the child's normal family caregivers, possibly including a grandparent or guardian.

5.1 Study population and recruitment

5.1.1 Childcare centre enrolment

Childcare centres in the Hutt Valley, Wainuiomata, Newlands and Johnsonville were enrolled in the study, if they agreed to participate and met the following criteria:

1. Not classed by the Ministry of Education as 'sessional' centres
2. Open for at least 8 hours per day
3. Child population attending the centre not expected to have an ethnic or cultural makeup highly disproportionate to other centres in the area
4. Children under two normally in separate areas from older children, or no children under two years old attending the centre

The childcare centres that met the first three criteria could be identified by web search, and were contacted by phone. Those that showed interest, and met the fourth criterion (from phone calls to centre managers) were invited to take part in the study, and were then emailed with information about the study (Appendix 5: Childcare centre and staff introduction).

Exceptions were a large national corporation that owned eight centres in the study geographic area, and a smaller national chain with two centres in the geographic area. The larger company declined involvement, while the smaller company initially responded, but did not respond to subsequent communication.

The centres that had agreed to participate were then followed up with a visit to enable the centre manager to meet the researcher, ask questions about the study, sign informed consent for the centre's participation in the research, and do the centre background questionnaire. The centre managers were asked to estimate the number of children likely to be attending their centre and eligible to be enrolled in the study during winter-spring 2017.

The total estimated enrolment pool from the 19 centres that agreed to enrol was about 650 children, short of the target of 800 children (see Section 4.3.2). To address the shortfall the study was extended to the northern Wellington suburbs of Johnsonville and Newlands (see Section 4.3.5).

Childcare centre consent form

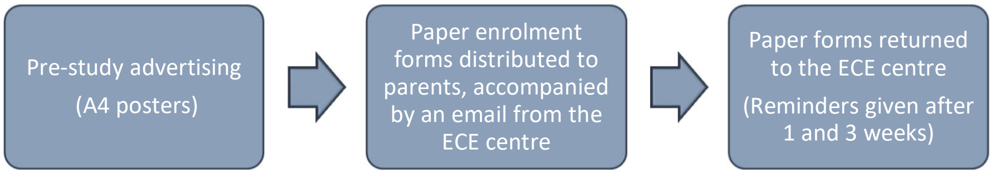
The consent form (Appendix 7: Childcare centre consent form) gave permission to collect temperature, humidity and CO_2 measurements, and to measure the area of the centre for the purpose of calculating space per person. It also provided consent to invite parents at the centre to enrol their children in the study. The consent form was signed by the centre manager, or a person who identified themselves as having authority for the consent. The consent form gave assurance that the identities of individual childcare centres and children would be kept confidential.

5.1.2 Child enrolment process (Figure 20)

With the assistance of the childcare centres, parents were alerted to the study with a poster (Appendix 8: Childcare centre poster) at the front door and/or the sign-in desk three weeks before enrolments commenced. Most centres sent an email to all parents and/or advertised the study on their childcare centre Facebook page.

The childcare centres then distributed enrolment packs to the parents (Appendix 9: Enrolment pack for parents).

Figure 20: Child cohort enrolment process



The enrolment packs contained:

1. An invitation to take part in the study, with the closing date for enrolments
2. A quick overview of the study – *How the study works* (A5, 105 words)
3. A detailed information sheet covering the reason for the study, study method, privacy, the study team and contact details (two sides, A4, 680 words)
4. A quick reference contact sheet (A5)
5. A child enrolment consent form (two sides, A4)
6. An ECEE study 'business card' with researcher contact details, and the child's study number for use when logging into the website

The child enrolment consent form assured parents that no information would be released that identified any individual child or childcare centre.

Enrolment forms were received at the childcare centres for collection by the researcher. As numbers were well below the study enrolment target by the due date, enrolment was extended for two weeks, with further reminders, giving a total of four weeks spent on enrolment after distribution of enrolment packs.

5.2 Illness and absence data collection, child and home questionnaires

5.2.1 Website pre-testing

The website format and questions had two pre-test phases:

1. In-house testing with university staff who had young children, to ensure logon procedures and controls were working, and to get an initial parent response to the questions

2. Pre-testing with parents of preschool children representative of the study cohort, using phone procedures exactly as they would be used in the study.

5.2.2 Website structure and implementation

The website was specifically designed for the ECEE study, and operated as a secure site with ‘https’ designation. The website used a plain, paged-form layout that worked well on a full-size screen or tablet, and could be used on a smart phone (albeit with very small font size). Logos were used on the login page to give assurance of authenticity and sponsoring organisations, but not on the questionnaire pages. The website contained three separate questionnaires:

1. The child’s health history questionnaire
2. The household questionnaire
3. The ongoing illness data entry form

The website logon page, continuity pages and questionnaire pages are reproduced in Appendix 10: Website pages. The questionnaires had data validation controls, and controls to prevent missed responses.

It was expected that following the first contact, which was by phone, the data collection would be at least 75% online. As the parent / caregiver cohort was likely to include some individuals with a disability or other limitation that would interfere with online data provision, such as dyslexia, visual impairment and/or unreliable connectivity, participants were given the option of phone calls rather than website use.

5.2.3 Threshold for illness data collection

The threshold for illness data collection was absence from childcare due to illness of at least half a day. This approach was necessary as many illnesses were likely to result in a child staying home, but not be severe enough to result in a visit to a medical doctor. This approach is similar to that taken by Enserink et al. in a 2009–2012 Dutch study[109], in which childcare centres only reported infectious disease episodes that resulted in absence of the child on one or more days that the child was scheduled to attend childcare In the ECEE study, parents were asked to record:

- Sick days, including any days when a child was ill enough that they would not have attended a centre if it was a normal day of attendance (so a weekend day would count as a sick day)
- Days off from childcare due to illness.

5.2.4 Childcare centre notifications of absence due to illness

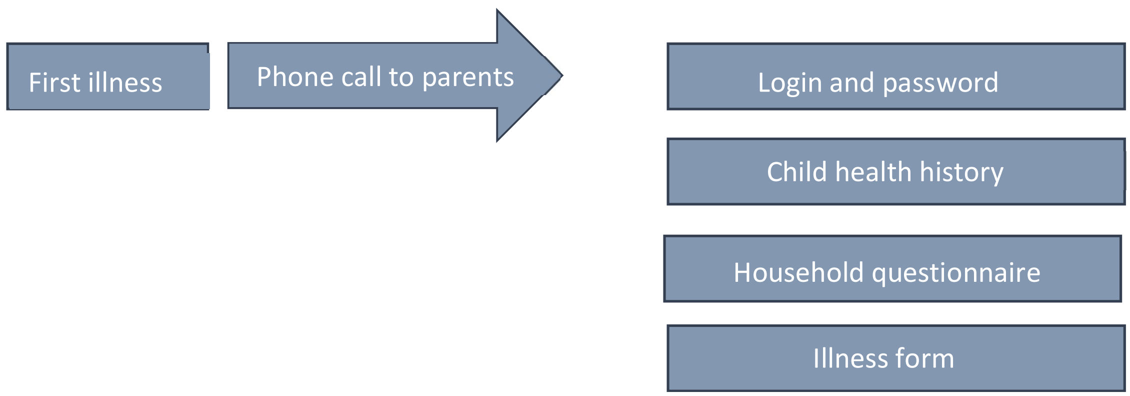
The childcare centres were provided with lists of those children who had been enrolled in the study. Each week every centre was sent an email with an updated list, against which to check absences. The centres were asked to email the list back to the researcher on Fridays, so that parents could be called by a researcher or sent a reminder text message at the weekend if possible. Weekends were chosen as the best time for initial contact and reminders, to reduce interruptions to parents during their work and elicit quicker responses.

5.2.5 Initial questionnaires for parents and introduction to the website process

The first time a child was away sick, the parent(s) were contacted by phone (Figure 21). The first contact included:

1. Introduction to the website and setting of a password
2. Completion of the child's health history and the household questionnaire
3. First time completion of the illness data form

Figure 21: First illness phone call – website introduction and background questionnaires



The child and household surveys were conducted on the phone to provide parents with an opportunity to ask questions, and to ensure completion of the longest questionnaires in the study. Parent(s) were then led through the illness questionnaire process, so that they would be familiar with the system when asked to do it on their own. There was a potential for hundreds of first-time call processes at about 15 minutes each. The use of the first-time illness to trigger the background questionnaire and system training process enabled a rolling start, rather than trying to contact all parents in a short period. Parents who had not been contacted within the first four months were then contacted irrespective of child illnesses.

Once the child health history and household questionnaires had been completed, the buttons for these questionnaires disappeared from the web page. For any subsequent completion of the illness form or commencement of a new illness form, the website was checked a week after the illness date, and parents were sent a text message reminder if no data entry had been made. If necessary, the text message reminder was followed by a phone call. An email reminder was sent if the parent(s) could not be contacted by text message or phone, and the centre manager was asked to mention to the parent(s) that the ECEE study researcher was trying to make contact.

5.2.6 Illness questionnaire process (parent data entry)

The website contained a questionnaire for the start of illness (Figure 22), a questionnaire for end of illness, and a continuity section to enable parents to indicate that their child was still unwell.

The website also showed a panel asking whether the child had been to a medical doctor (GP) or hospital. The purpose of the text and the doctor / hospital question was to check on the seriousness of the illness, so that any further contact with parents could be handled appropriately (see Appendix 10: Website pages).

If the answer to 'Are they still away sick?' was 'No', the respondent was then directed to the page for completion of illness information. This page repeated the questions about symptoms and doctor / hospital visits or diagnosis, and asked questions regarding the number of days sick for the child and parents, days off work, and other household members getting sick with the same infection.

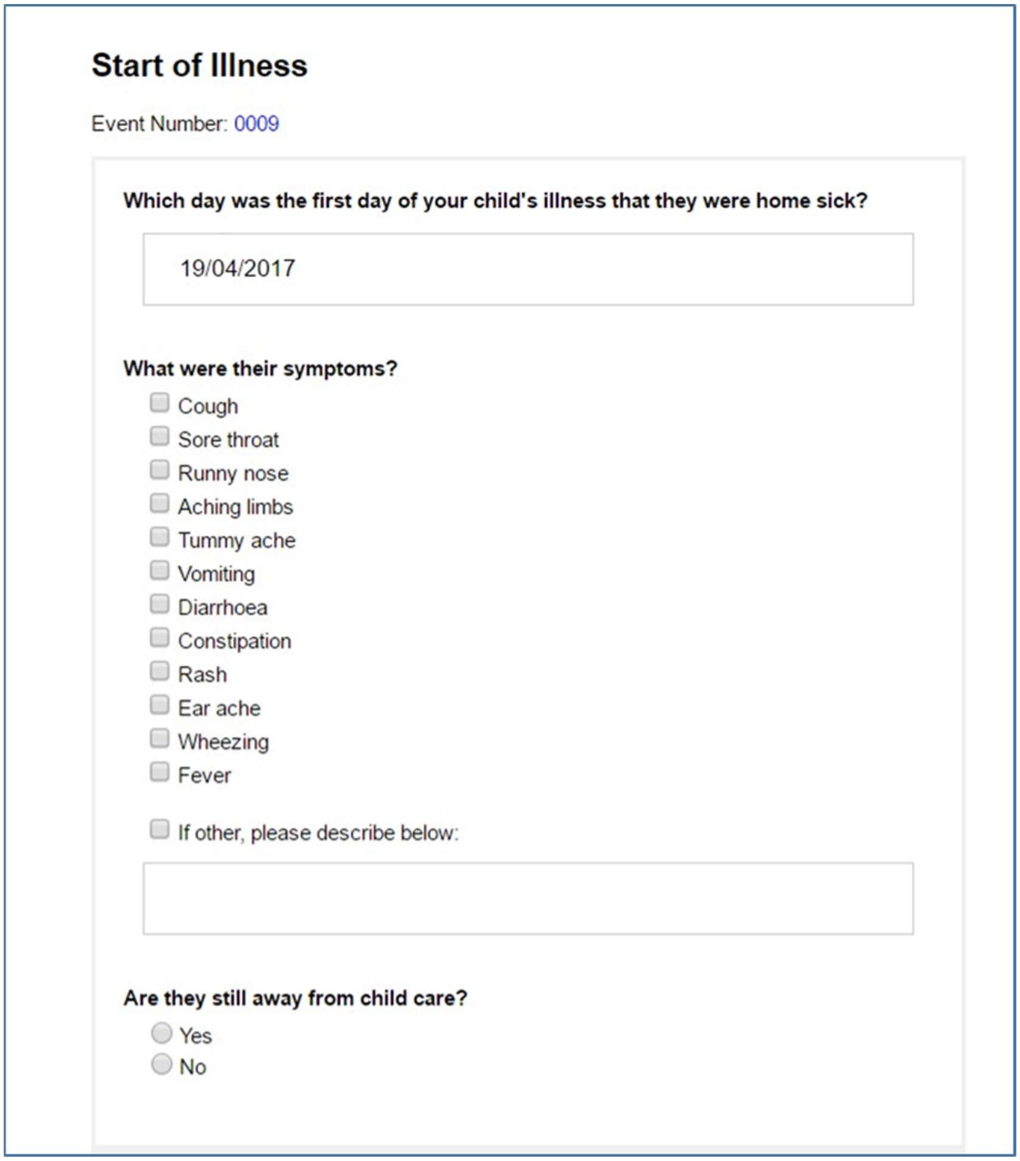
Child history and home environment questionnaires

A number of extraneous variables were included in the children's histories and home environments.

The child history questionnaire included:

- Ethnicity
- ECE centre attendance before two years old (including age at first attendance)
- Rating of child's general health
- Illnesses in the last 12 months
- Asthma and wheezing history

Figure 22: Start of Illness screen



Ethnicity

In New Zealand, the concepts of 'ethnicity' and 'ethnic groups' have been defined by the Statistical Standard for Ethnicity 2005 as follows:

> Ethnicity is the ethnic group or groups that people identify with or feel they belong to. Ethnicity is a measure of cultural affiliation, as opposed to race, ancestry, nationality or citizenship. Ethnicity is self-perceived, and people can belong to more than one ethnic group [214].

A 2008 paper by the Ministry of Health Public Health section noted that more people are identifying with multiple ethnicities. For example, in the 2001 Census, 9.0% of people identified with more than one ethnic group, and this increased to 10.4% in 2006. In a study described in the same paper, using 2002/03 New Zealand Health Service data, the Ministry found that comparisons using total response ethnicity are similar to comparisons using prioritised ethnicity [215].

The ECEE study background questionnaire used 2013 NZ Census ethnicity categories, with the addition of separate categories for 'Chinese' and 'Indian', and allowed parents to allocate multiple ethnicities for their children.

Home environment

The household questionnaire included:

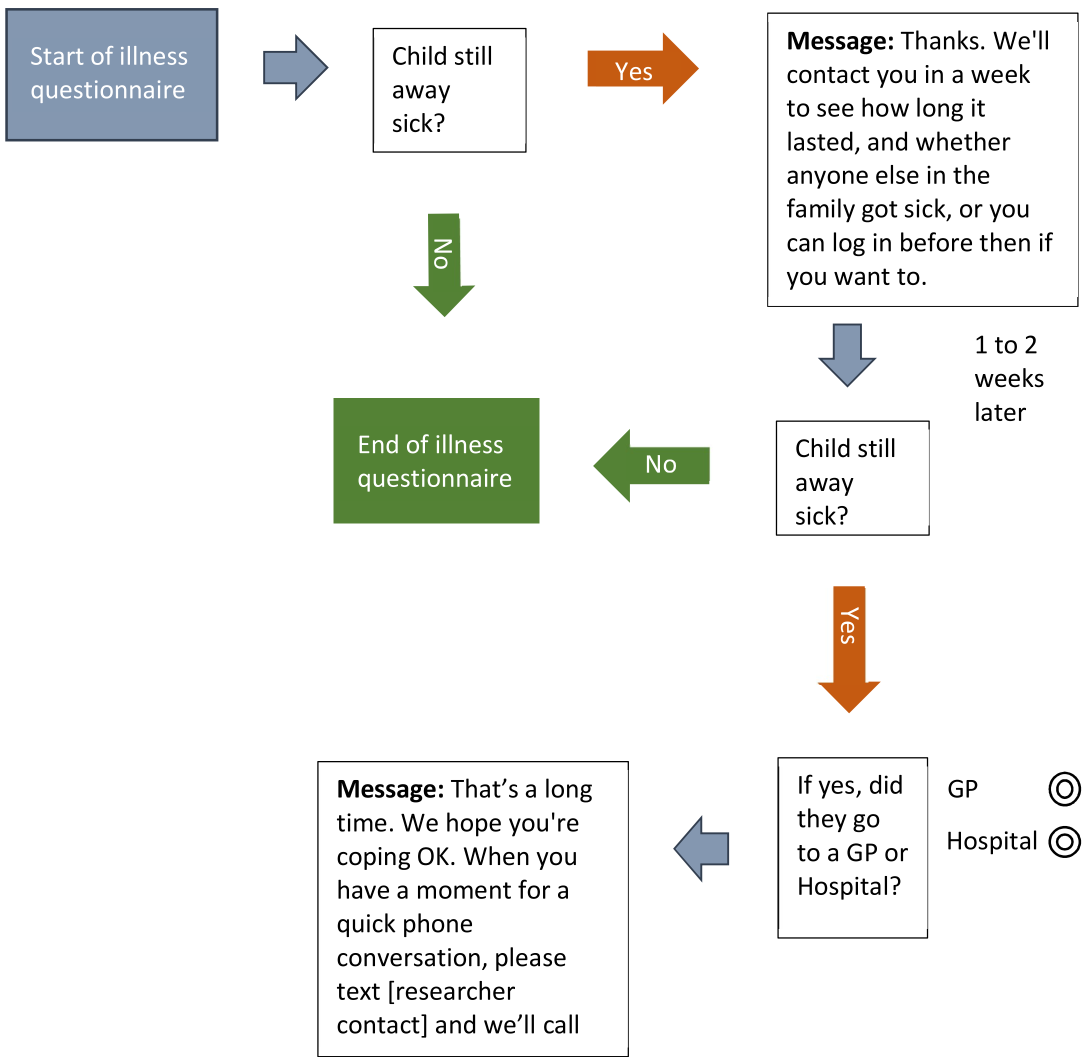
- The number of bedrooms in the house
- The number of people normally living in the house
- Smoking in the house
- Other children in the house attending ECE
- Other children in the house attending school
- Perceptions of house coldness, dampness and mustiness
- Use of the Community Services Card
- Household income

The questionnaires are reproduced in Appendix 10: Website pages.

5.2.1 Tracking of illness reports

Initial parent contact, background questionnaire completion and illness reports were tracked on a calendar and checked against a database of reports from ECE centres of children presumed away sick. If a child was absent during a given week, this information was entered on the calendar. It was then checked against reports from the website that showed whether or not illness reports had been completed and/or reminder text messages sent or calls made to parent(s) / caregiver(s). This system also allowed recording of withdrawals from the study, temporary child absences, e.g. due to overseas travel, or other information such as circumstances that would affect appropriateness of contact with parents.

Figure 23: Typical website process for illness questionnaires



5.3 Measured environmental characteristics of childcare centres

Indoor environmental parameters measured were:

1. Temperature (°C)
2. Activity area (m^2) per child and per person
3. Relative humidity (%RH)
4. Peak CO_2 concentrations in sleep rooms (ppm)

Prior to the first visits to the childcare centres (Stage 1) there had been an intent to measure air volume per person, but this was dropped from the study due to the complexity of air spaces. Some centres had low-level divisions between activity areas by age group, or open airspace connection to utility areas such as bathrooms or kitchens. The complexity of air flow with multiple spaces and frequent opening of external doors meant that air volume was not a useful parameter for the study.

5.3.1 Area per person

Activity areas were measured with a laser measure during Phase One of the study, with a check prior to the main data-gathering phase to identify any spatial changes since the first measurements were taken. Some results indicated contravention of New Zealand ECE Service licensing requirements, based on the centre manager's indication of maximum occupancy, and Education Review Office reporting of maximum licensing. These spaces were re-measured in February-March 2018, after the second-phase data collection period. In each case the initial measurements were confirmed, so the results were discussed with the centre management to see if there was an explanation for the apparent breach of licensing requirements. During this process the manager was assured that, although the overall findings of the study would be discussed with the Ministry of Education, the individual childcare centre would not be identified.

The Ministry of Education Early Learning Information system (ELI) was used to obtain attendance data for each day of the study to calculate crowding. The Ministry of Education was able to provide data that differentiated age groups, meaning, for example, that data was available for a space allocated to children two years to three and a half years old, differentiated from a space in the same centre for older children.

Ministry of Education data was limited to attendance at the childcare centre. It could not be taken as a measure of actual indoor crowding, as children tend to have free access to outdoor areas at most times of the day.

5.3.2 Temperature and relative humidity monitoring

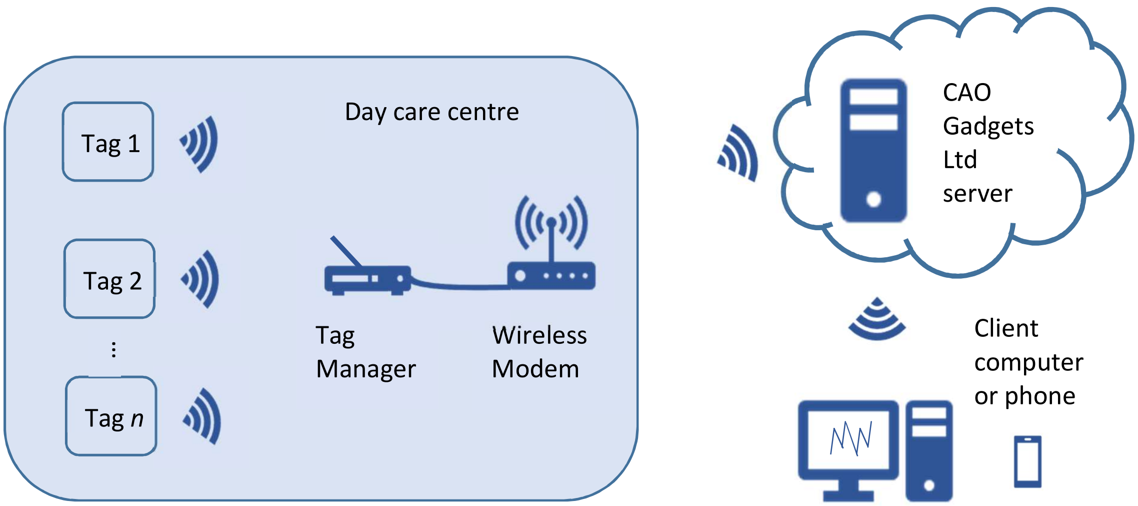
Temperature and humidity measurements were taken at 15-minute intervals over five months. The Tags were located between 0.5m and 1.0m above the floor, consistent with the New Zealand Ministry of Education *Criteria for Licensing* requirements for Early Childhood Education Services. For safety, all Tags were screwed to walls or joinery to prevent removal. Analysis of room temperatures and humidity involved the complexities of room use and the variability of building layout. The objective in deployment of Tags was to measure the environments experienced by children in a representative way, avoiding locations close to exit doors and heating appliances. Where centres had only one activity and sleep space (combined), one or two Tags were deployed depending on the size and shape of the space and the location of the heating system in relation to exit doors. Where children had use of two or more rooms, Tags were located in the rooms, with information obtained from centre management as to the use of rooms.

There had been an intention to use rainproof Tags for outdoor measurements, but they failed the calibration tests described in Section 0. The outdoor measurements with Tags were replaced with New Zealand Meteorological Service data.

5.3.3 Wireless Tag system, internet security and electronic device safety

The Tags had sensors for temperature, humidity, movement and battery strength, while the Tag Manager also recorded Tag signal strength. Each Wireless Tag had a default range of up to 210m, communicating with a Tag Manager. The Tag Manager received data from each of the Tags within range, and controlled the frequency of data collection. The Tag Manager sent the Tag data to CAO Gadgets Ltd, from which the data was available for download to the client's computer. The devices could also be controlled from a smartphone.

Figure 24: Wireless Tag System



The Wireless Sensor Tag Pro devices had inbuilt memory to cover periods of lost connectivity. Each centre was provided with instructions for resetting the residual current device (RCD) and to check that the Tag Manager was working (Figure 25). These instructions were provided to enable staff to reconnect the device when they knew it had been temporarily offline. Wireless routers devoted to the Wireless Tag system were used in all centres. The Tag Managers and Wireless modems were located away from child access, with RCD protection in case of electrical faults.

Tag event alerts and reconnections

The Tags and Tag Managers were set to provide the following alerts:

- Movement of the Tag as an alert to tampering (optional setting)
- Low battery strength (automatic)
- Tag 'out of range' – meaning no signal from the Tag (automatic)
- Tag Manager offline (automatic)

Figure 25: Re-setting the Tag Manager

5.3.4 Tag calibration and performance

All Tags were calibrated in the University of Otago Centre for Translational Physiology controlled environment chamber, which has manufacture rated accuracies of +/- 0.4°C and +/- 1.3% RH, and calibration test accuracies of +/- 0.1°C and =/- 0.4% RH. Data from 10 tags were analysed during two temperature and RH cycles as follows:

Test Cycle 1

90 minutes: 16°C reducing to 12°C over 1½ hours at 55% RH.

Test Cycle 2

210 minutes: 12°C increasing to 20°C with simultaneous increase in RH from 55% to 85%. Tag data were matched to room data to within +/- one minute of measurement points. The one-minute variance occurred because, while the room gave readings every minute, the Tag data timing was dependent on the Tag Manager communicating with an individual Tag. This meant matching 240 room measurements to between 18 and 24 Tag measurements over the same four-hour period.

The Tags had a maximum variance from the room measurement of +/- 0.6ºC, with an average variance range during the test cycle of +/- 0.12ºC to 0.23ºC (Table 8). Maximum humidity variance during the 90-minute cycle with stable RH was +/- 1.64%, with an average variance range of 0.31% to 0.83%. It was evident, however, that the Tags were not able to keep pace with the 30% increase in RH over four hours.

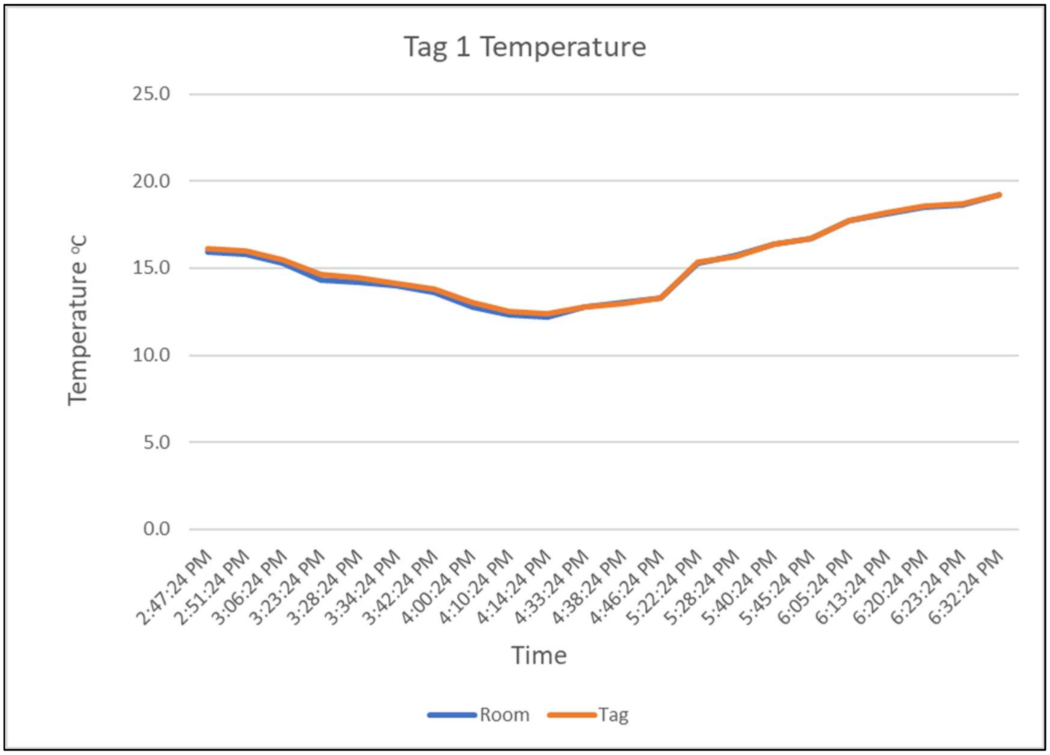
Table 8 shows typical Tag performance in the first test cycles, and it is shown in graphic form in Figure 26.

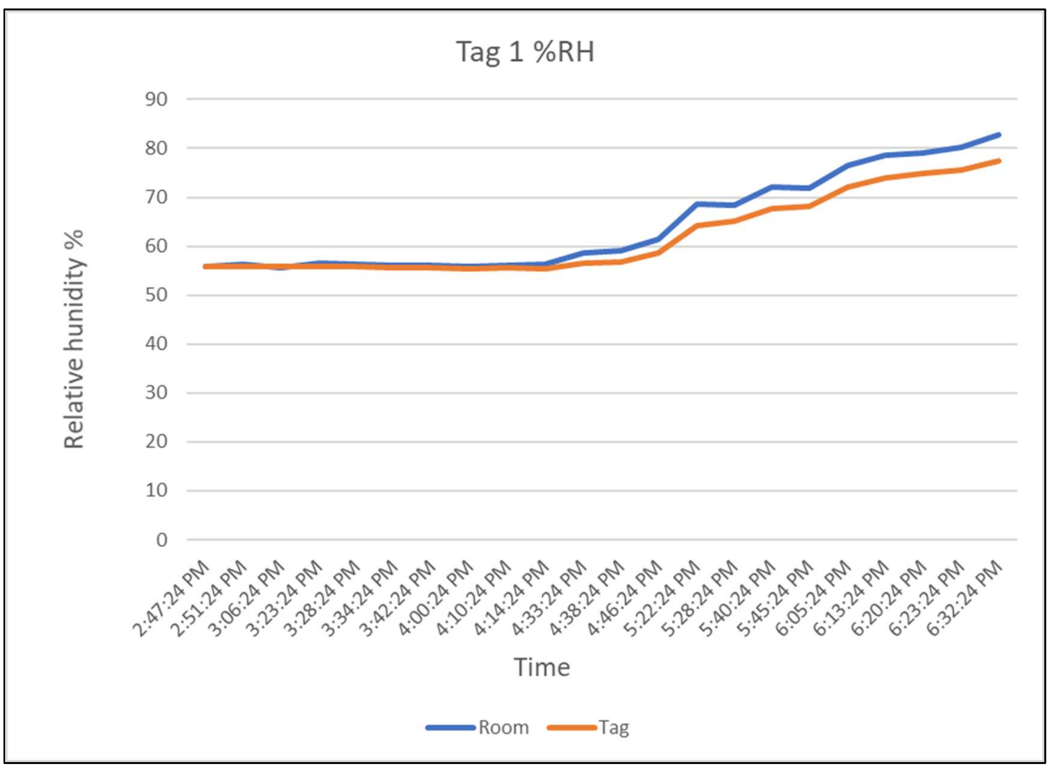
Table 8: Tag variance

Tag	Temperature ºC		Humidity % RH stable	
	Av variance	Max variance	Av variance	Max variance
1	0.12	0.33	0.38	0.87
2	0.19	0.47	0.47	1.29
3	0.23	0.51	0.79	1.29
4	0.23	0.55	0.79	1.64
5	0.22	0.47	0.31	0.75
6	0.21	0.50	0.23	0.31
7	0.19	0.32	0.83	1.07
8	0.22	0.42	0.60	0.80
9	0.17	0.46	0.31	1.07
10	0.20	0.60	0.80	1.37

The response lag was discussed with Dr Manfred Plagmann, Senior Physicist at BRANZ. Dr Plagmann supplied previous test data for Tag performance undertaken by BRANZ, showing variation in performance depending on sensor exposure. Unfortunately, the Tags have very small pinhole air vents to transfer air to the sensor, reducing response time. An improvement could be achieved by drilling a 4mm hole in the cover directly over the sensor, while excellent performance could be achieved by removing the sensor cover and reversing the circuit board to directly expose the sensor.

Figure 26: Tag response





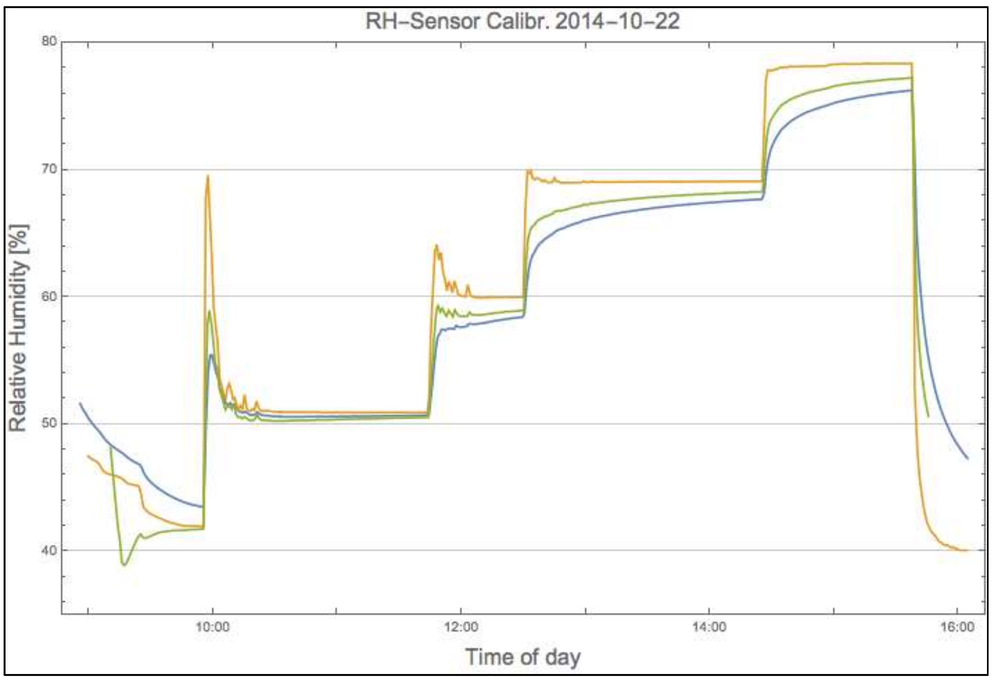
The following graph shows sensor response for:

Unmodified Tag

Tag with 4mm hole

Tag with exposed sensor

Figure 27: BRANZ comparison of Tag RH response with Tag modification (supplied by Dr Manfred Plagmann, BRANZ)



The ECE centre environment with Tags located at child height made the exposed sensor arrangement unsafe, so the option of the 4mm hole was used as the best compromise between safety and response (see Figure 28).

Figure 28: Tag modification

Unmodified tag | Tag with 4mm hole | Tag with exposed sensor

5.3.5 CO_2 concentrations

CO_2 measurements were taken in sleep rooms using a HOBO mx 1102 CO2 sensor, with a manufacturer's accuracy rating of ±50 ppm ±5% of reading at 25°C and less than 70% RH and 1,013 mbar. Adjustment for pressure is 0.13% of reading per mm Hg. pressure. Measurements were used during periods of normal use, on one occasion each of one to five days per centre, to identify CO_2 levels that might indicate a need for further research.

5.4 Observed and teacher-reported environmental attributes and practices

5.4.1 Centre preliminary visits, questionnaire scope and pre-testing

In addition to area measurements, a number of environmental attributes were recorded during Phase One of the study.

These included:

- The type of heating systems used, and teacher or on-site manager perceptions of heating effectiveness and efficiency
- Active and passive ventilation systems
- An outside door directly connected to the activity space
- Covered outdoor space for wet weather play

- Teacher or on-site manager observations of dampness, window condensation or mould
- The number of handwashing stations in the toilet area
- The number of handwashing stations in the activity space

The visits provided the opportunity to observe heating and ventilation systems as well as recording the staff descriptions. The type of heating system was recorded, with notes on any conditions that would affect performance, e.g. location of a heat pump next to an outside door. The questionnaire asked whether a specific minimum temperature was being aimed for, and for an assessment of heating effectiveness and efficiency. Effectiveness was defined as a rating of the ability of the heating system to achieve the desired temperature, while efficiency was a rating of the cost of achieving the desired temperature. Effectiveness and efficiency were user-rated on a 1 to 5 scale, from poor (1) to excellent (5). These questions were supplementary to the main study questions. The purpose was to compare actual indoor temperatures recorded by monitoring Tags with expectations, systems and perceived performance.

The questionnaire is reproduced in full in Appendix 11: Childcare centre Phase 1 questionnaire.

The questionnaires were used in person-to-person interviews with on-site managers and/or delegated staff. The questionnaires were trialled in two iterations, interviewing at two ECE centres for each trial. The centres in the trial would have been eligible for the full study, except that they had activity areas that included children under two years old. In other respects, they were representative of the study population. Minor changes were needed for each iteration. The second iteration changed the heating effectiveness and efficiency responses to a 1 to 5 scale rather than using ‘excellent’, ‘good’, ‘not very good’, ‘poor’ or similar options. Other changes provided for extra comments or question clarification.
The centre questionnaires included questions related to some behavioural disease transmission risk factors. The list of questions was designed to reveal significant hygiene risks, rather than to be exhaustive.

5.4.2 Child handwashing facilities and practices in childcare centres

Facilities

The questionnaire identified handwashing facilities in the toilet area and activity spaces separately. Most centres now use wash troughs with one tap per user, rather than individual basins. Handwashing was counted according to the number of children who could use the facility at one time.

The Ministry of Education *Criteria for Licensing* requires a minimum of one handbasin to fifteen children over the age of two years. This ratio is associated with the number of toilets required, and does not reflect other handwashing needs such as handwashing after messy play or before meals. Some ECE Services have provided additional handwashing facilities in the activity spaces to reflect this need. The number of handwashing facilities does not absolutely determine practice, but affects ease of implementation of handwashing routines.

Handwashing practices

The questionnaire also asked for observations of handwashing practices. The person answering the questionnaire was asked to respond according to observed practices rather than policy, recognising that especially with children, reality can vary from best practice. Handwashing-related questions included:

- Do children usually wash their hands after toileting?
- Do children usually wash their hands after nose-blowing?
- Do children usually wash their hands before eating?
- Do children usually dry their hands well after handwashing?

5.4.3 Nappy change practice

The questions around nappy change were designed to reveal common faults in practice or understanding, rather than to provide detailed information. Three common faults were addressed in the following areas:[d]

1. The perception of gloves as a hygiene precaution. A person wearing gloves during nappy change is less likely to be aware of contamination on the gloves than they would be of contamination on bare hands. This can lead to contamination of surrounding surfaces and objects. Mandatory wearing of gloves is common but not based on analysis of contamination risks.

2. Failure to disinfect areas around the nappy change pad, rather than just the pad itself – related to wearing of gloves.

3. Failure to have children wash their hands after nappy change. Children can easily contaminate their hands during nappy change, but the focus tends to be on the adult washing their hands rather than the child.

The questionnaire asked:

- Does your nappy change policy require mandatory wearing of gloves?
- How often is the area around the nappy change pad disinfected?
- Do children usually wash their hands after nappy change?
- Do teachers usually wash their hands after nappy change?

5.4.4 Disinfection and cleaning

There were two additional questions on disinfection and cleaning, again in part to find out whether the centre was following the advice of the Wellington Regional Public Health Unit. From 1996 to 2016 the Wellington Regional Public Health Unit had advised 1:100 diluted

[d] From personal experience as an Early Childhood Centre health programme coordinator for Wellington Regional Public Health 1992–2009.

supermarket bleach for cleaning the pad and surrounding area, except in cases of diarrhoea or vomiting in any area, for which 1:10 diluted bleach was recommended [e].

5.4.5 Comfort toys and playdough

There were two questions related to 'comfort toys' and playdough, as these are play items likely to receive a lot of hand and mouth contamination, which can therefore act as fomites in a childcare environment.

5.5 Ethics approval and confidentiality

Ethics approval for the ECEE study was obtained from the Health and Disability Ethics Committee (HDEC) of the New Zealand Ministry of Health. An observational study requires HDEC review only if the study involves 'more than minimal risk'. The ECEE study was identified by HDEC as 'more than minimal risk' on the basis that:

- some participants will not have given informed consent to participate
- one or more participants are vulnerable (that is, participants who have restricted capability to make independent decisions about their participation in the study).

Although consent was obtained from all adult participants (parents, and childcare centre management), the children were not themselves giving consent, and for this reason fitted the category of having restricted decision-making capacity.

Confidentiality and sensitivity to family circumstances

The key ethical issues addressed in design and management of the ECEE study were:

- Confidentiality
- Sensitivity to child and family circumstances

[e] From personal experience as an Early Childhood Centre health programme coordinator for Wellington Regional Public Health 1992–2009, and subsequent personal communication. Disinfection information was missing from the Regional Public Health revised website from mid-2017 and was not on the website in October 2018.

The centre and child enrolment process included the following assurances:

From the childcare centre and staff introduction (Appendix 6) When we publish information from the study, we won't be identifying any individual ECE Service or any people. We will match child and teacher health to the days they experience different temperatures, humidity or space per person. To be able to measure exposures this way we'll need to get attendance information each week – who was away, and who was away sick. The website used by parents and teachers to enter illness data will be confidential. Enrolment details will be kept separate and secure, not on the website.

From the parent enrolment pack (Appendix 9) The University of Otago will keep your information private and confidential. The information from the study that is made public will only be about environmental conditions and illnesses – there won't be any names or childcare centres identified. The website will be confidential, but even there your child's name and address won't be included – only a study number. The enrolment details with your child's name, age and address will be kept separate and secure, not on the website.

Sensitive circumstances such as serious child illness were managed in three ways:

1 The website for illness data entry included checks for hospitalisation, and a comment if a child had a prolonged illness (see Appendix 10):

That's a long time. We hope you're coping OK. When you have a moment for a quick phone conversation please text [phone number] and we'll call you back.

2 Communication with centre managers about any circumstances that might require cessation of contact, or sensitive management.

3 Tracking of text conversations with parents so that any call or text received could be managed appropriately, within the context or previous communication.

5.6 Analysis

5.6.1 Overview of analysis steps

Data analysis required the following steps:

1. Data cleaning – identification of missing or inconsistent data, including follow-up with parent(s).

2. Calculation of summary data, for example, median temperatures, or area per child data derived from floor area measurements and Ministry of Education attendance data. Childcare centre managers were contacted to check crowding data that indicated breach of regulations (to check for possible incorrect allocation of age-groups to spaces).

3. Conversion of data from categorical to ordinal where appropriate.

4. Creation of three seasonal data sets – winter, spring and winter-spring (full study period).

5. Data aggregation by Centre ID number and Child ID number.

6. Univariate analysis, including histograms and boxplots for data distribution, and including comparison between the study population and the study sample, for example, by ethnicity.

7. Simple bivariate analysis – scatter plots.

8. Identification of outliers or points of influence.

9. Univariate Poisson regression to identify predictor variables likely to be of best fit for nested generalised linear models (GLMMs). A nested model was necessary because

the data was derived from a cohort of children attending a range of centres, producing exposures in common across smaller groups of children (random effects modelling).

10. Testing of GLMMs for best fit to describe at least the predictors for the outcome of days sick per child, and if possible, for outcome subsets such as respiratory illness or enteric illness.

11. Checks for confounding or collinearity.

5.6.2 Childcare centre temperature and humidity data

The temperature and humidity data were recorded at 15-minute intervals, but these intervals were not synchronous between individual Tags. This meant that tables of synchronised data needed to be created from the raw data, using linear interpolation to assign quarter-hour temperature and humidity measures, with empty cells returned if the Tag had provided no raw data within 60 minutes of one or both sides of the quarter-hour.

Data needed to represent all day conditions, but there were times when Tags were offline for parts of a day. This meant that some days could not be included because of incomplete data. To avoid excessive loss of data (for example, deleting a day because one measurement was missing), an inclusion criterion of days with not less than 90% representation was applied. Data were removed for weekends and holidays. The childcare centres in the study were open from 7:00 a.m. or 7:30 a.m. to 5:30 p.m. or 6:00 p.m., except for one which was open 8:00 a.m. to 4:30 p.m. To allow a warm-up time, and to avoid times when children were not present, only data from 8:30 a.m. to 4:30 p.m. was used for analysis.

Relative humidity data was checked for interference (for example a child directly breathing onto Tags, splashing or other events), that could create a false high reading, by identifying any readings of over 90%. Reading that were inconsistent with readings in the previous and subsequent hour were rejected.

5.6.3 Childcare centre CO_2 data

CO_2 data were plotted as line graphs for identification of CO_2 peak levels and the relationship between CO_2 level rise and decline and room use. The results were compared with BRANZ recommendations and the Ministry of Education design guidelines for school classrooms (see Section 3.3.4).

5.6.4 ECE centre reported and observational data

Centre questionnaire variables that could directly affect illness rates included:

- Sick child attendance and collection of sick children
- Handwashing procedures
- Cleaning
- Ventilation

These data were a mixture of categorical and ordinal data. The ordinal variables were converted to scores as shown below for Poisson regression and random effects modelling.

Sick child attendance

These variables were assigned a score to indicate the likelihood that sick children would be present at the centre, combining the frequency of parents bringing sick children, the frequency of children being sent home during the day, and the difficulty in getting parents to collect a sick child. Scores were calculated as a percentage of the highest possible score of 12 (3 variables x score of 4), with a high score being the worst.

Values were assigned to the categorical responses as follows:

- Very often 4
- Often 3
- Occasionally 2

- Rarely 1
- Never 0

Handwashing

Not all centres had children in nappies (diapers), resulting in different score denominators for handwashing. For this reason, handwashing scores were calculated as a percentage of the highest possible score, with a high score being best. Values were assigned to the categorical responses as follows:

- Always 4
- Almost always 3
- Sometimes 2
- Rarely 1
- Never 0

Cleaning

Cleaning practices were assigned a value of 2 for recommended practice, 0 for poor or 'unknown' practice, and 1 where an intermediate value was reasonable. Scores were calculated as a percentage of the highest possible score of 12, with a high score being best.

For the questions:

- How often is the area around pad disinfected?
- How often are objects around nappy change pad disinfected?

  The values assigned were as follows:

- More than once daily 2
- Once daily 1
- Less frequently than daily or not sure 0

For the questions below, values were assigned as No = 0, Yes = 1.

- Is dilute bleach used for nappy change disinfection?
- Are soft toys shared?
- If soft toys are shared, are they washed at least daily?
- Is fresh playdough supplied at least daily?
-

5.6.5 Child age, ethnicity and health data, and home environment data

The child variables used in the regression analysis were:

- Age of the child at the start of the research period (12 June 2017), as decimal years.
- Attendance at early education or care before two years of age (No = 0, Yes = 1)
- Ethnicity
- Sex (M/F)

The home environment variables data used in the regression analysis were:

- Number of people normally living in the house
- Number of bedrooms in the house
- Person-to-bedroom ratio (derived from the counts of bedrooms and the number of people normally sleeping in the household)
- Smoking inside the house (Y/N converted to No = 0, Yes = 1)
- Count of other children in the house attending early education or care
- Count of other children in the house attending school
- Use of a Community Services Card (No = 0, Yes = 1).
- Questions related to experiences of coldness, dampness or mould (categorical data converted to ordinal data)

For house conditions, the conversion of categorical to ordinal data was as follows:

- Yes, always 3
- Yes, often 2
- Yes, sometimes 1
- No 0

The use of census categories provides for a check of the sample population against the expected population, but for regression analysis these categories were converted to prioritised ethnicity, using the following groups.

- Māori 1
- Pacific Island 2
- Asian 3
- NZ European 4
- Other 5

An additional category 'Māori or Pacific' was created for use in the regression analysis.

5.6.6 Linear regression analysis

Because of the large number of variables in the set, univariate regression was used to screen out those variables not likely to have a significant effect. Outcomes for centre variables (sick days per child) were expected to (and did), approximate a normal distribution. For centre variables (e.g. space per child, temperature, or humidity), the IBM program SPSS (version 25) was used to calculate single-predictor linear regression, with the outcome sick days per child, using the model:

$$\text{outcome}_\text{i} = b_i + \text{e}_i\,\text{x}_i + \varepsilon_\text{i}$$

where:

b = intercept
e = centre environment covariate
x = observed value
ε = error
i centre environment (1, 2…23)

The following SPSS settings were used:

```
Generalized Linear Models.

GENLIN (outcome variable) WITH (predictor variable)
MODEL (predictor variable) INTERCEPT=YES
DISTRIBUTION=NORMAL
LINK=IDENTITY
CRITERIA SCALE=MLE COVB=MODEL PCONVERGE=1E-006(ABSOLUTE)
SINGULAR=1E-012 ANALYSISTYPE=3(WALD)
CILEVEL=95 CITYPE=WALD LIKELIHOOD=FULL
MISSING CLASSMISSING=EXCLUDE
```

For analysis by child, the model needed to take into account clustering because children were attending different childcare centres, and needed to allow for a Poisson distribution for individual outcomes. Univariate Poisson regression was calculated using the statistical software ‘R’ version 3.5.1 (2/7/18) ‘Feather Spray’, and the GLMER function from the R package ‘lme4’ (CRAN version 1.1-7), using the model:

$$\ln(\text{outcome}) = b_{0i} + (c_{1ij}x_{1ij}) + \varepsilon_{ij}$$

where:

b = intercept

c = child or home covariate

x = observed value

ε = error

i centre environment (1, 2…23)

j = child 1, 2…221) for all seasons, (1,2…220) for winter

The R syntax used was:

Output filename <-glmer (child sick half days ~ child or home covariate + (1| centre_ID), family = ‘Poisson’, data = (source data filename)

The covariates for the multivariate model were selected based on significance and effect size, and then added to the model in the form:

$$\ln(\text{outcome}) = (b_{0i} + (e_{1i}x_{1i}) + (e_{2i}x_{2i}) \ldots + (e_{ni}\, x_{ni}) + (c_{1\,ij}x_{1ij}) + (c_{2ij}\, x_{2ij}) \ldots + (c_{nij}\, x_{nij}) + \varepsilon_{ij})$$

where:

b = intercept
e = centre environment covariate
c = child or home covariate
x = observed value
ε = error
i centre environment (1, 2…23)
j = child 1, 2…221) for all seasons, (1,2…220) for winter

The syntax used for the GLMER function was:

Model name <-glmer (outcome variable name~ **hypothesis covariate$_1$** + covariate$_2$…+ covariate$_n$ + (1| centre_ID), family="poisson", data= (source data filename)

An iterative process was used, starting with the hypothesis covariates (area per child, temperature and humidity). Variables were added in order of the lowest Akaike's Information Criterion (AIC) value until a best-fit model was achieved for each of the hypothesis covariates that were selected for inclusion in the generalised linear mixed model (GLMM).

Checks were made for multicollinearity by two methods:

1 A correlation table was generated for predictor variables using the MS Excel data analysis add-in for Excel 2016.
2 When adding predictor variables to the GLMM, a check was made for any large increase in the standard error of the intercept cause by a specific variable.

5.7 Research process timelines

Figure 29: Phase 1 research process timeline

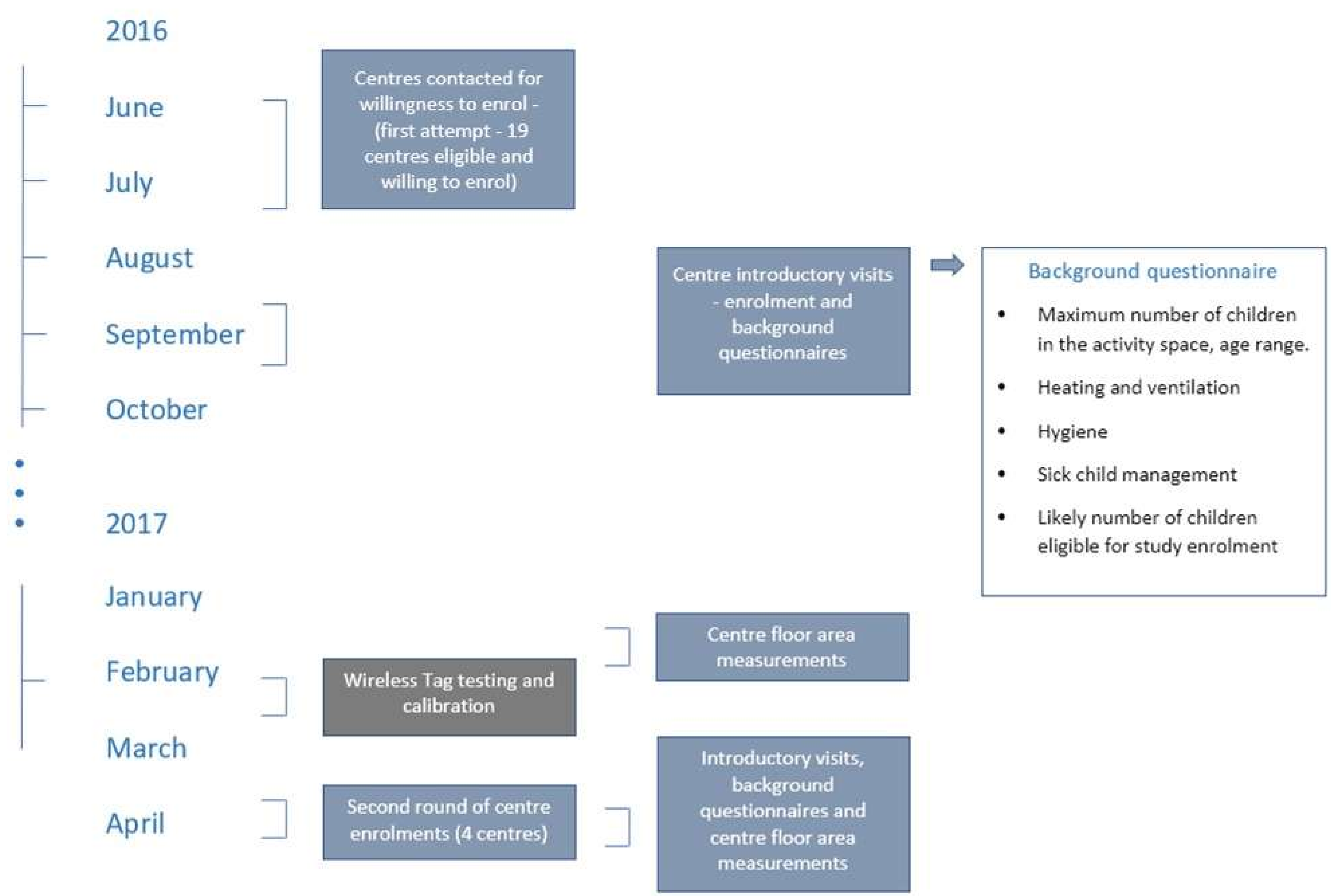
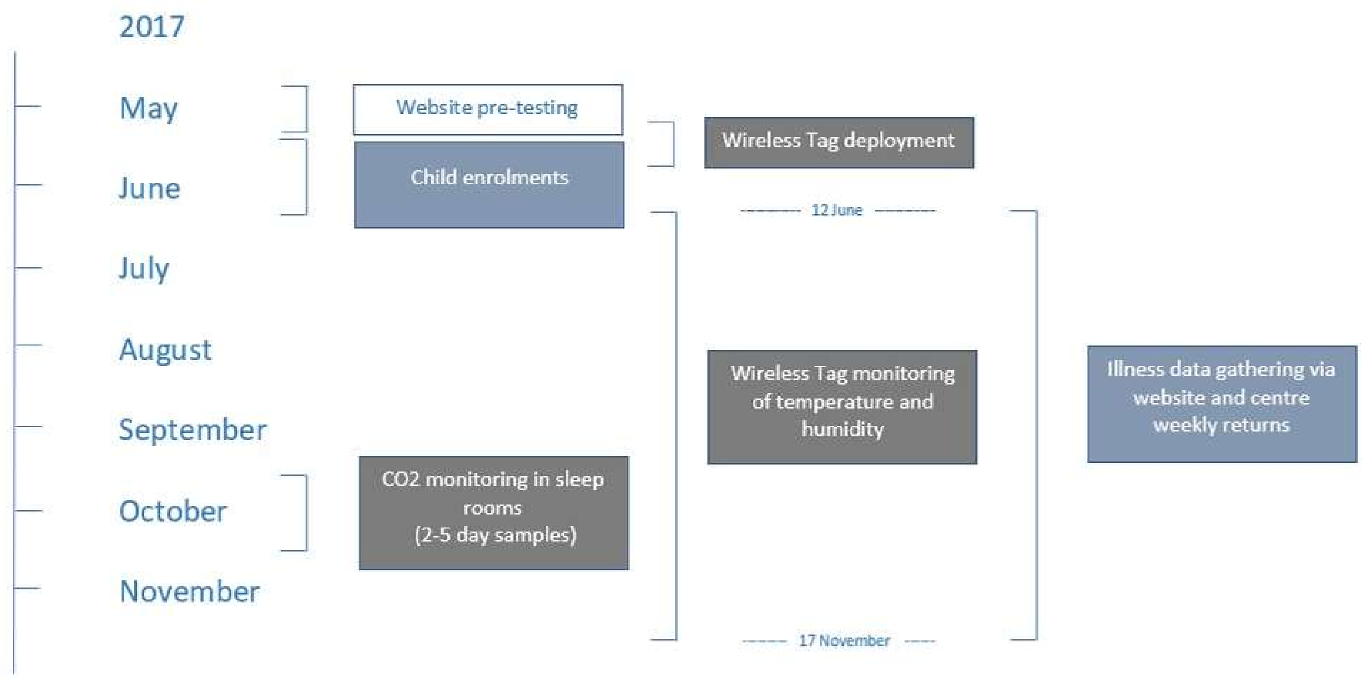


Figure 30: Phase 2 research process timeline



6 Results and analysis

6.1 Data collection systems – participation and performance

This section describes the centre and child cohort engagement with the study, and aspects of the study method implementation; for example, website use and researcher time demand.

6.1.1 ECE centre enrolments and participation

The result of the first attempt to enrol childcare centres prior to Phase One of the study is shown in Table 9. Nineteen centres were enrolled in the first round, with two of these centres having separate areas for age groups within the two to five year age range, giving a total of 21 environments. These centres provided estimates of numbers of children that would be eligible to enrol in the study in 2017, with a total estimated pool of approximately 650 eligible children. As this was substantially less than the estimated target pool of 800 children, enrolments were extended to the suburbs of Johnsonville and Newlands (refer to Section 4.3.6). The second round of centre enrolments took place in April 2017, with responses as shown in Table 10.

Table 9: First round of childcare centre enrolments

Enrolled		19
Ineligible due to mixed-age environment or insufficient hours of attendance		11
Initial response but no subsequent reply from management		6
Declined	Management saw no value in study (one large chain)	8
	Perceived workload	5
	Concern about implications of study findings	1
	No reason given	1
Total		**52**

Table 10: Second round of childcare centre enrolments

Enrolled		3
Ineligible due to mixed-age environment or insufficient hours of attendance		2
Declined	Perceived workload or study implications	2
	Manager absence during study	1
Total		**8**

The second enrolment process brought the total number of enrolled centres to 22, with 24 separate environments. One of the centres then declined to enrol children due to management stress, so the results for that centre are limited to temperature, humidity and floor space. The total number of centres fully participating was 21, with 23 environments.

6.1.2 Child enrolments and participation

The initial estimated pool of children eligible for enrolment was 799 across the original 22 centres, but by the time child enrolments commenced in May 2017 it became apparent that centre managers had underestimated the numbers of eligible children. After one centre withdrew, the actual number of children in the pool of those likely to be eligible at the time of enrolments, based on revised centre management estimates, was 884. The number of children enrolled at the commencement of the study was 260 (29.4% of children suggested as eligible), with three enrolments later in the year, for a total of 263 or 29.7%. Some of the 884 children in the estimate pool would have been ineligible, however, if they had a sibling in the same space at the ECE centre, or if they attended more than one ECE centre. These constraints were explained in the enrolment pack (see Appendix 9: Enrolment pack for parents), so some parents would not have attempted to enrol those children.

Engagement of the childcare centres with the enrolment process varied considerably. Enrolment rates by centre ranged from 9.1% to 62.5% (Table 11), with an average enrolment rate of 29.1%. Some centres were very active in seeking enrolments, contacting parents individually to encourage them to enrol their children. Others simply left the enrolment packs near the sign-in table for parents to collect if they wanted to.

Table 11: Total numbers of children two years to five years old at each centre

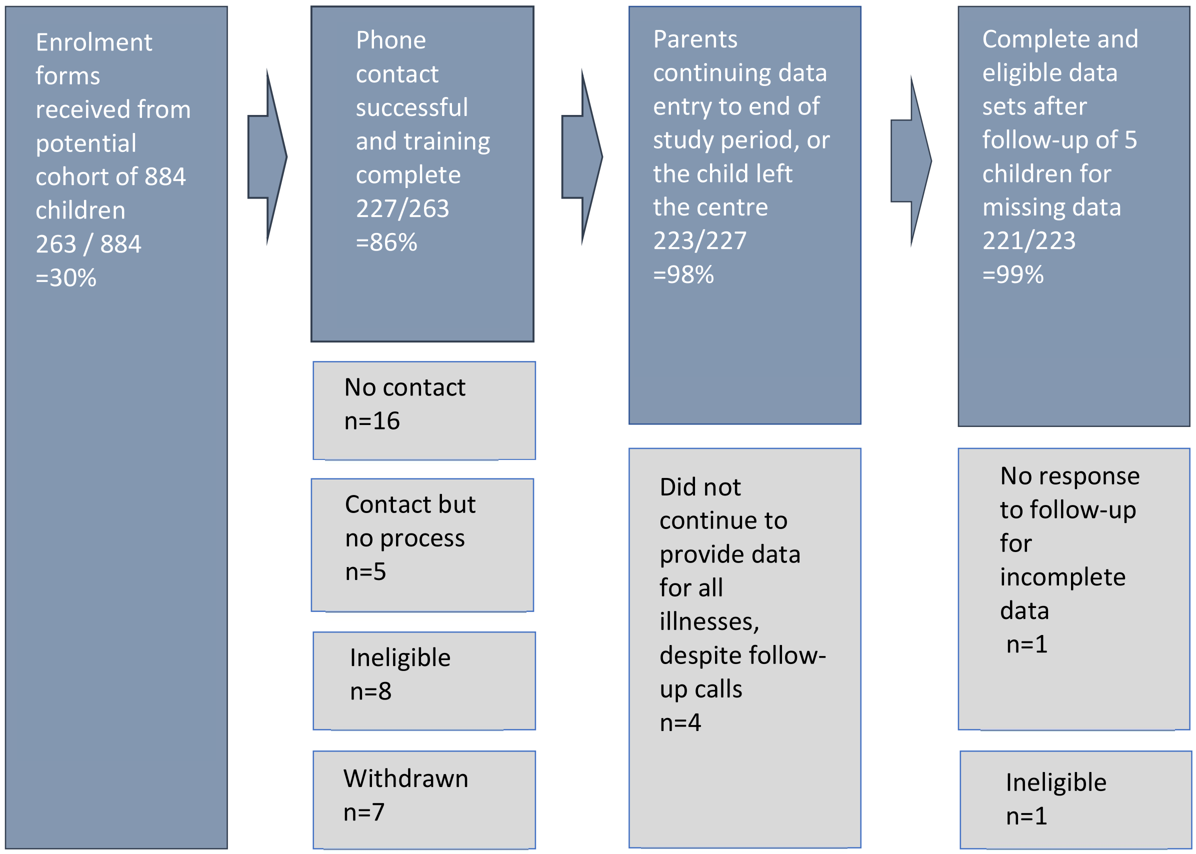
Environment number	Number enrolled in the ECEE study	Max children in activity area	% enrolled in the ECEE study	Minimum age	Maximum age
1	8	40	20%	3	5
2	11	24	46%	3.75	5
2.1	2	22	9%	2.5	3.75
3	8	25	32%	2	5
5	5	30	17%	2	5
6	10	39	26%	2	5
8	13	24	54%	3	5
9	6	24	25%	2	5
10	14	24	58%	2	5
11	8	28	29%	2	5
12	3	22	14%	2	3
12.1	8	35	23%	3	5
13	15	20	75%	3	5
15	12	45	27%	2.5	5
16	14	30	47%	2	5
18	7	50	14%	2	5
19	11	41	27%	2	5
20	10	35	29%	2.5	5
23 & 24	21	63	33%	2	5
25	7	30	23%	2	5
28	10	30	33%	2	5
29	4	29	14%	2	5
30	14	50	28%	2	5
Total	221				
	Average	33	30%		

Enrolments included children who turned five years old and consequently started school during the study, and a few children left the centres for other reasons. A total of 32 children left during the data collection period. The data for these children were included in study findings, but represented a reduced sample of exposure to conditions.

6.1.3 Website training, data entry and completion

Of the 263 children enrolled, 227 (86%) had the website training completed by a parent, along with the child questionnaire and home questionnaire (see Figure 31).

Figure 31: Total enrolments and data entry completion



Of the 227 parents who completed the initial process, 223 (98%) continued with the study to the point of website closure. Of these 223, five required follow-up for missing data (illness event partly filled or background data missing). Only four of these five parents could be contacted, so one child's data could not be included due to missing background information. Three parents had completed the initial illness questionnaires but not the final illness questionnaires, and these were for illnesses that had not been recorded by their ECE centres and were therefore not tracked for follow-up. Calls were made to the parents and the missing data was added to the database. Another two parents had missed the child health history questionnaire (possibly a research team member omission or a website fault). One child was found to have been ineligible due to age (under two years old). The final cohort was 221 children for winter-spring, and 220 children for winter only.

6.1.4 Data cleaning

Data cleaning revealed 18 single-cell data entry errors, such as obviously incorrect dates or inconsistent or unlikely numbers, which were addressed in one of two ways:

1. Imputation by inference from other data: for example, days of attendance or the tracking system for reported time off sick.
2. Parents contacted for data errors that could be not be resolved otherwise.

Of the 18 errors, 17 were resolved. One error (a reported 30 influenza events for one child in the previous year) could not be resolved as the parents could not be contacted, so it was treated as missing data.

In addition to single-cell data entry errors, one illness event had been entered as two illnesses, and one entry was for an absence that was not an illness.

6.1.5 Childcare centre returns and sick child attendance

The centre managers provided a return each week identifying the children in the study who were presumed away sick (see Appendix 12: Example of centre weekly email – sick children). In many cases the centre management could not know the reason for absence until the following week, so these returns were only a prompt to check for website data entry by parents. ECE attendance is not compulsory in New Zealand, and centre managers reported that it is common for parents to have their children away without reporting the reason to the ECE centre at the time. Follow-up with parents found many instances of absence that were not illness-related, indicating that childcare centre absence reports are not reliable as a proxy for child illnesses.

6.1.6 Researcher time demand for parent and centre management communication

While the overall completion rate for parents who started the website process (98%) was very good, the parent reminders and the time required to maintain contact was considerable. First-time contact calls frequently required a number of text messages and brief calls before a successful introductory call was completed, and parents often required more than one text message or call to remind them to log in and complete an illness event entry. In the six months from the start of the data collection period to the closure of the website, first-time introductory calls and follow-up calls for illness-related data entry required a total of 1,021 outgoing calls and 2,440 outgoing text messages. This number does not cover return calls and text messages from parents to the study mobile number.

The average time required for the introductory phone call process was 18.7 minutes, which was close to the initial expectation from pre-testing of 15 minutes. The most common reasons for a longer call time were a problem with the parent's internet connection, or English as a second language.

The weekly returns from centres to indicate which children were presumed off sick was a vital part of the follow-up system, but it was also time-consuming. Sending weekly emails (which needed to be updated each week for each centre) required 2–3 hours work per week. Most weeks, between 25% and 50% of the centres did not respond without phone and/or email prompts, requiring additional time for checking and follow-up.

6.1.7 Participant fatigue and teacher / manager stress

The proposed data collection period had been eight to nine months, starting in autumn 2017, but due to delays with environmental monitoring equipment and website development, it was reduced to five months. Despite the reduced time for the study, both parents and centre managers became increasingly hard to contact, and made fewer self-initiated entries or responses during the last two months of the study. The 98% completion rate was in part due to very determined follow-up of parents (multiple calls and text messages per child) in the three weeks between study period end and website closure.

While it is a subjective impression, the levels of stress among centre managers and teachers appeared high. Three of the centre managers had left their positions by the end of the study, and follow-up with these managers confirmed that stress was an important reason for leaving.

6.1.8 Wireless Tags for temperature and RH monitoring

A total of 58 Tags were deployed in 21 centres, comprising 23 separate environments. Tag deployment per centre ranged from one to five. Tag deployment and room use is listed in Appendix 13: Tag deployment.

The Wireless Tags system presented two reliability problems as deployed:

1. System power turned off or power failure.

The system should have provided notifications when contact with Tag Managers or individual Tags was lost, but the notification system was unreliable. The use of residual current devices (RCDs) for safety meant that the system would not automatically start when power came on again, so a manual system power reset was required. The loss of data for more than a small part of the day would result in a whole day of data being lost, as the daily data would not be representative of diurnal variations (see Section 5.6.2). Unfortunately, few centre managers and teachers could be relied on to reset the system without being contacted by phone. On some occasions the teacher answering the call could not leave children to reset the system, and the centre did not resolve the issue until the next day or even later. This could result in the loss of two to three days' data. Few Tags were seriously affected, however. While one Tag was only operational for 67% of the time, all others ranged from 83% to 100% of the time, with a mean of 94%.

2. Tags moved or damaged.

Two Tags were moved without notification by staff. The Tag movement detectors should have made it possible to retrospectively identify the date when the Tag was moved, but the movement notification setting proved unreliable. For one of these two Tags loss of data was not critical, as there were other Tags in the vicinity. For the other Tag, some spring data was lost. One Tag had damage to the relative humidity sensor, probably from water or paint.

6.2 Sample populations

6.2.1 Child cohort demography

Gender

The cohort was slightly unbalanced with respect to gender (Table 12), with the imbalance opposite to that of the Ministry of Education record of enrolments in Education and Care Services for Wellington, Lower Hutt and Upper Hutt cities [20].

Table 12: Child cohort gender compared with Ministry of Education record of enrolments

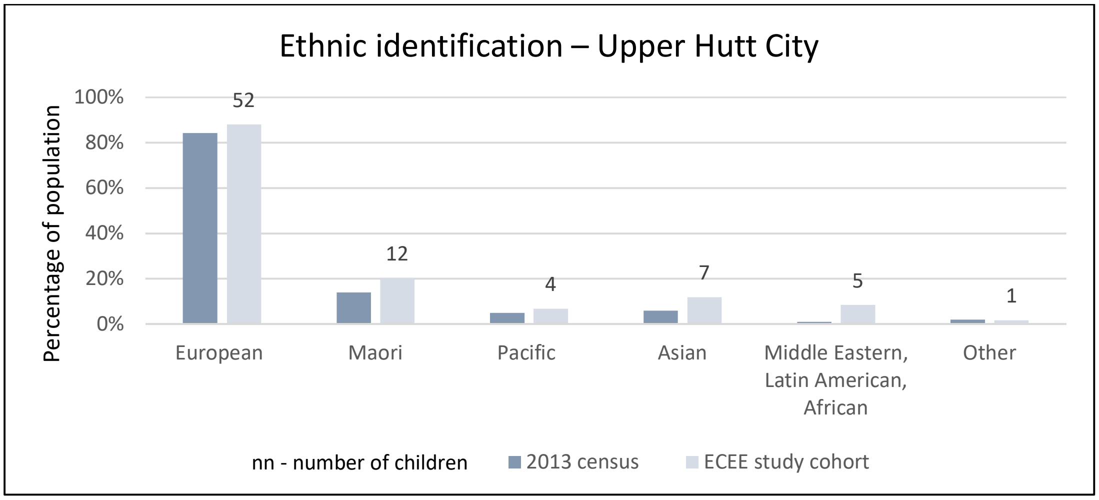
Data set	Girls		Boys	
ECEE study	119	53.8%	102	46.2%
Ministry of Education		48.7%		51.3%

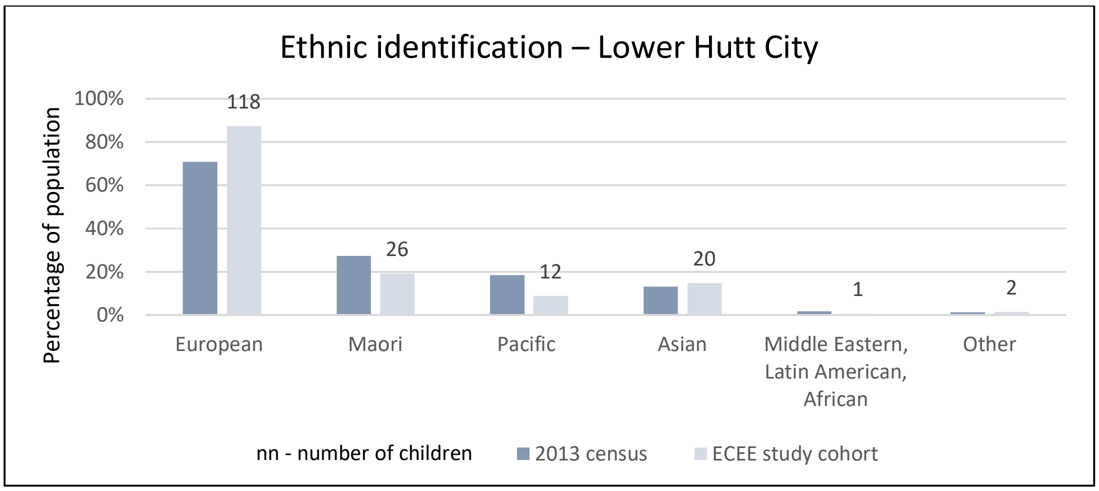
Ethnicity

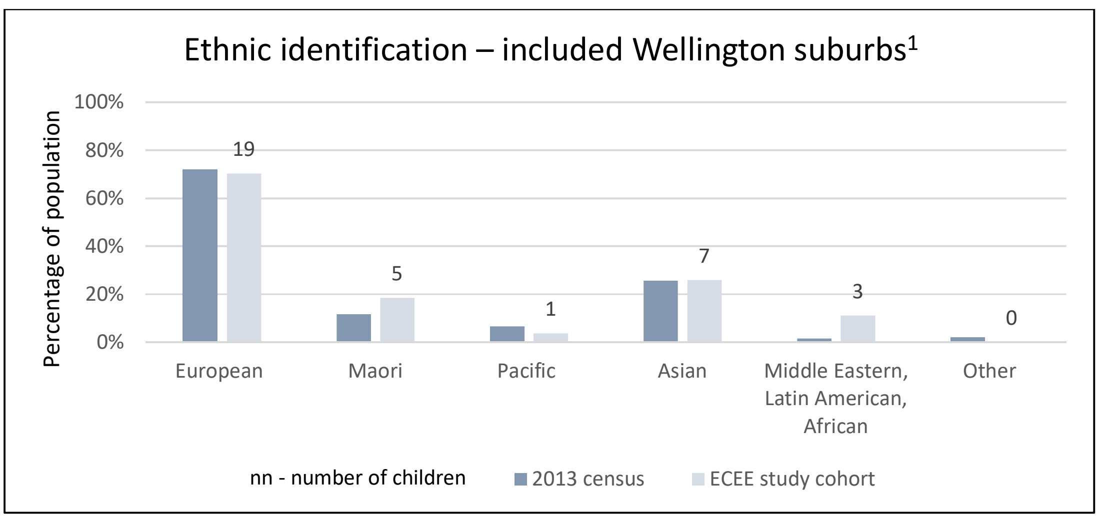
The graphs in Figure 32 show ethnic identity for children under five years old from the 2013 New Zealand Census [198], compared with the ethnic identities recorded on the ECEE study website. As more than one ethnic group could be selected, the total percentages are greater than 100% and the total for the ethnic identity counts will be greater than the number of participating children. The consistent higher percentages across ethnic groups in the Upper Hutt City ECEE study data suggest a larger proportion of children with multiple ethnic identities than in the Census data (although the numbers may be too small to be conclusive).

The Ministry of Education has ethnicity data for children enrolled in ECE services, but the Ministry data does not use multiple ethnicity, so their data are not comparable to the ECEE website data. The Ministry of Education data showed that Lower Hutt has twelve Kōhanga Reo, compared with three in Lower Hutt and six in the whole of Wellington City [20]. The larger number of Kōhanga Reo in Lower Hutt may account for the lower proportion of Māori children attending the ECEE study Lower Hutt childcare centres, compared to Upper Hutt and Wellington.

Figure 32: Child cohort ethnicity compared with Census data





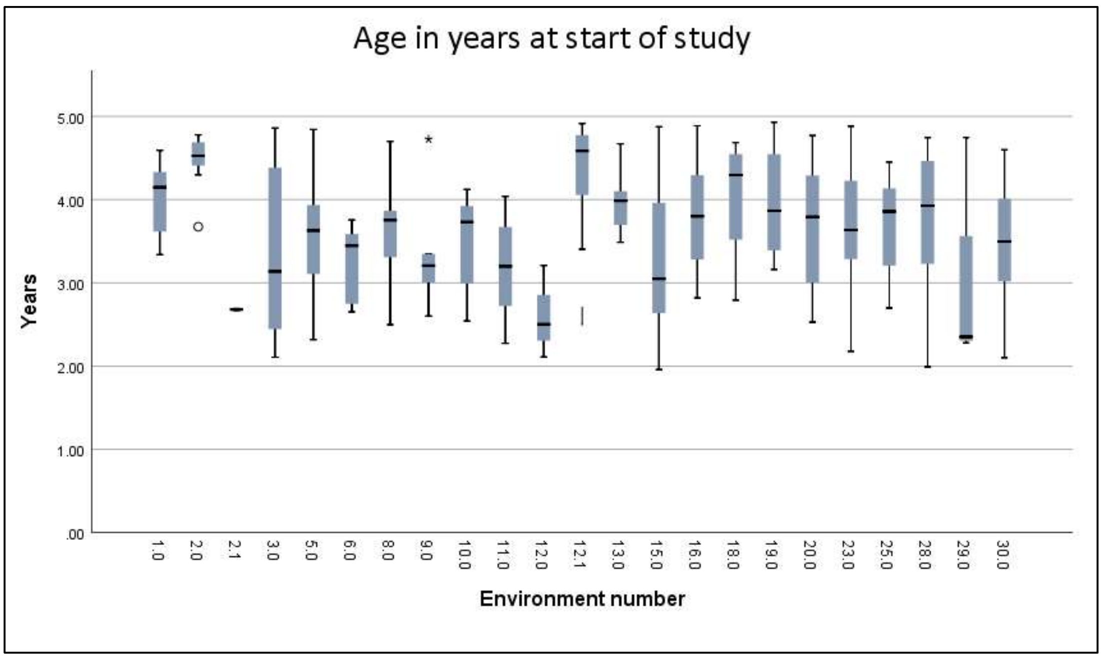


Note: Census data shown are only for the Wellington suburbs lived in by children in the ECEE study cohort.

Age

The study was limited to children aged two to five years, and included two centres that had age-group divisions within the two to five year age range. The first of these was centre number 2, which had an area for children over 3¾ years (environment 2.0) and another for children two years to 3¾ years old (environment 2.1). The second was centre number 12, which had an area for children under three years (environment 12.0), and another for children three years to five years (environment 12.1).

Figure 33: Age in years at start



The age range of children at the start of the study was 1.96 years to 4.93 years, with two children enrolled in the study just before their second birthdays (Figure 33). These two children were included in the study as the activity areas they used were designated for children two years old or more. The median age at the start of the study was 3.73 years, but as shown in Figure 33, there was a considerable variation in median age and age distribution across the environments in the study.

Note: In Figures 33, 235 and 36 the blue boxes represent the 25th to 75th percentile range; the horizontal line inside the box represents the median value; and the 'whisker' ends represent 5th and 95th percentile values. The o and * symbols represent value outside the 5th to 95th percentile range.

Socio-economic status

There were two measures of economic status – combined household income and Community Services Card (CSC) use.

34 (15.4%) of children came from homes using a CSC. Unfortunately no data was found for the study locality for CSC use, so it was not possible to verify that the CSC use was representative of the population. The data will provide a reference for other similar studies of the parents of children in childcare.

Combined household income is shown in Figure 34. Five of the respondents did not know their combined income (this was in some instances due to self-employment without regular income), while another five preferred not to say. Category variables were assigned to the remaining income groups (1 = $20,000 – $40,000… 9 = Over $180,000) to estimate a median income category. The median household income category was $100,000 – $120,000. The most recent available New Zealand Census data (2013) shows median household income for Wellington city as $91,100, for Lower Hutt City as $69,500, and for Upper Hutt City as $68,400. These values are considerably lower than the median household income in the study data, but this was to be expected for two reasons:

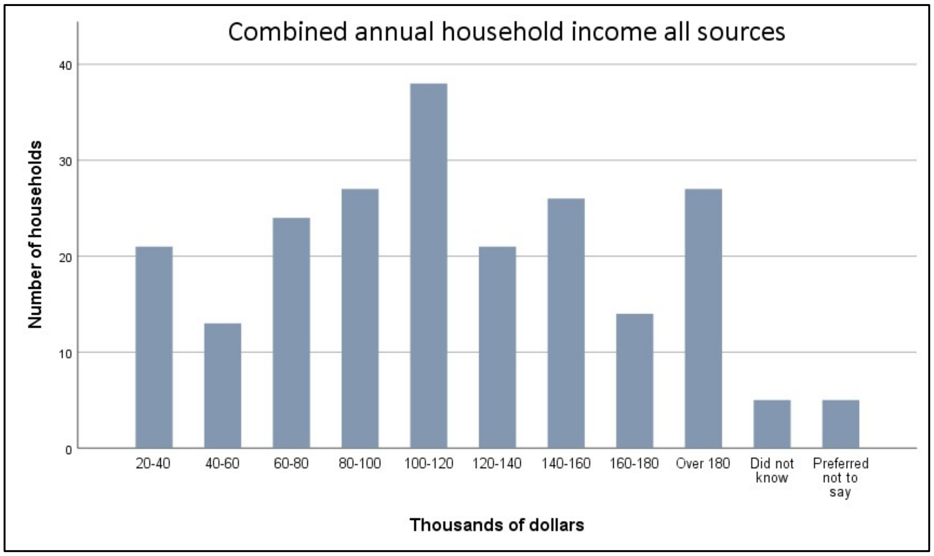
- The most recent available census data is from 2013. Income will have increased in dollar terms between 2013 and 2017

- The households in the study cohort are characterised by having at least one child in childcare, and for many this was full-day care. Full-day care is needed where a sole parent or two parents are in full-time work. This would skew the income data towards higher combined household incomes. The census data includes all households, including those with a single beneficiary as the sole occupant, and those on retirement incomes.

The second factor in particular means that the study income data cannot be meaningfully compared to census data, but as for CSC use, the data can be use as reference for future studies. For another comparison, a 2011-2012 University of Otago study in the Wellington

Region with a similar child age grouping (1-7 years) found a median household income in the study cohort at that time of \$80,000 to \$100,000 [216].

Figure 34: Combined annual household income



6.2.2 Child cohort childcare attendance data

Hours and weeks of attendance

Although the centres in the study all had full-day operation, some children attended less than five days per week, or for a small number of hours per day. Attendance hours at the start of the study ranged from 6.75 hours per week up to 55 hours per week, with a median of 32.50 hours and mean of 33.95 hours (see Figure 35). Most children (91.4%) attended for a total of 18–22.8 weeks, but some were in attendance for fewer weeks, either because they had started school during the study period, or because they had moved to another location.

Total attendance ranged from 27 hours (4 weeks at 6.75 hours per week) up to 1,254 hours (22.8 weeks at 55 hours per week), with a median of 720 hours and mean of 731 hours (see Figure 36). 160 children (76.5%) had attended some form of early education or care before they were two years old. For the children who started before two years old, the starting age ranged from one month to 24 months, with a median of 11 months.

Figure 35: Attendance – hours per week

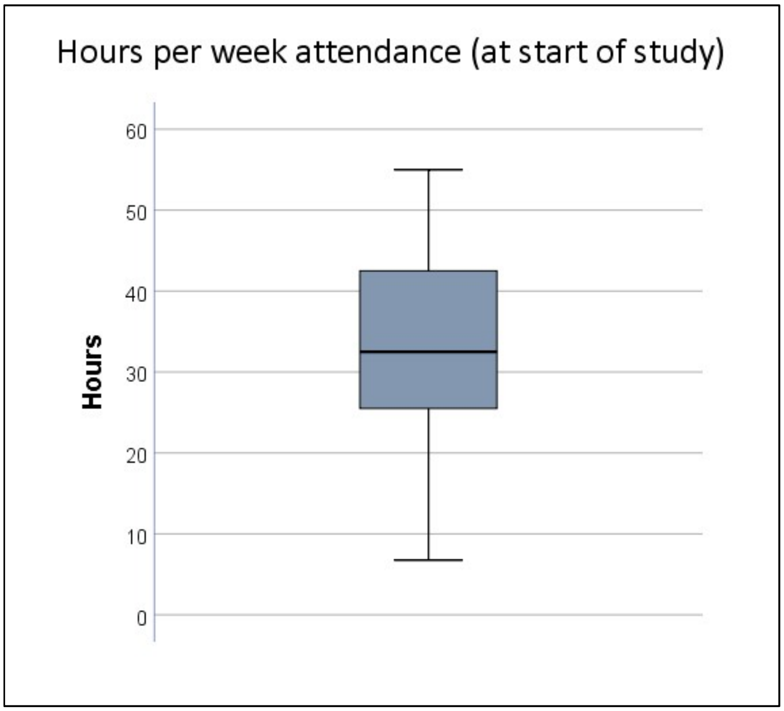
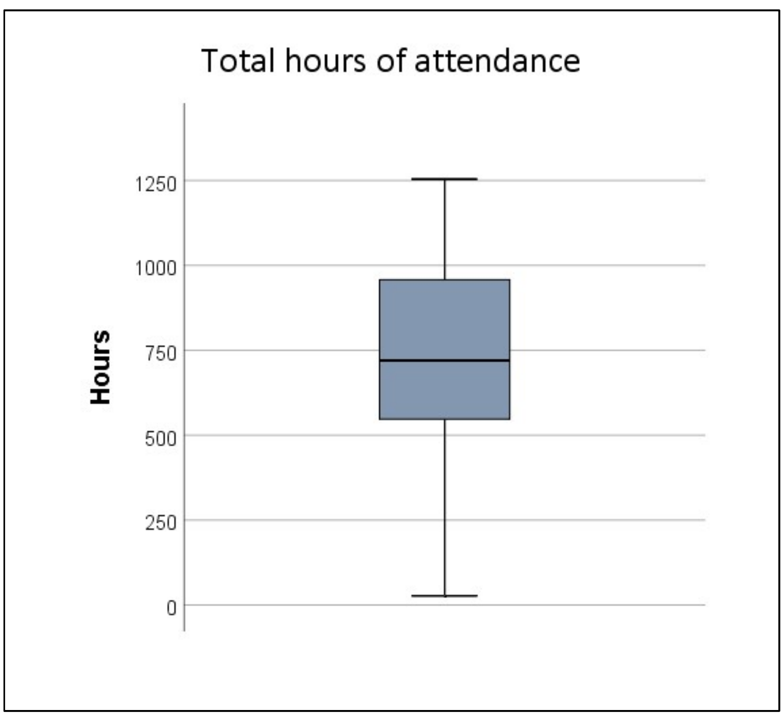


Figure 36: Attendance –total enrolled hours during the study period



6.2.3 Child health history

Parents mostly rated their child's health at the beginning of the study as excellent or very good (78.3%), with only one child's health rated as poor (Table 13).

Table 13: Parent rating of child health at the commencement of the ECE study

Parent's rating of child's health	n	%
Excellent	84	38.0
Very good	89	40.3
Good	35	15.8
Fair	12	5.4
Poor	1	0.5
Total	221	100.0

Parents provided a count of illness episodes during the 12 months prior to the study, for a number of illnesses categories, as shown in Table 14. The background illness information provides a cohort profile for comparison with future studies of a similar type.

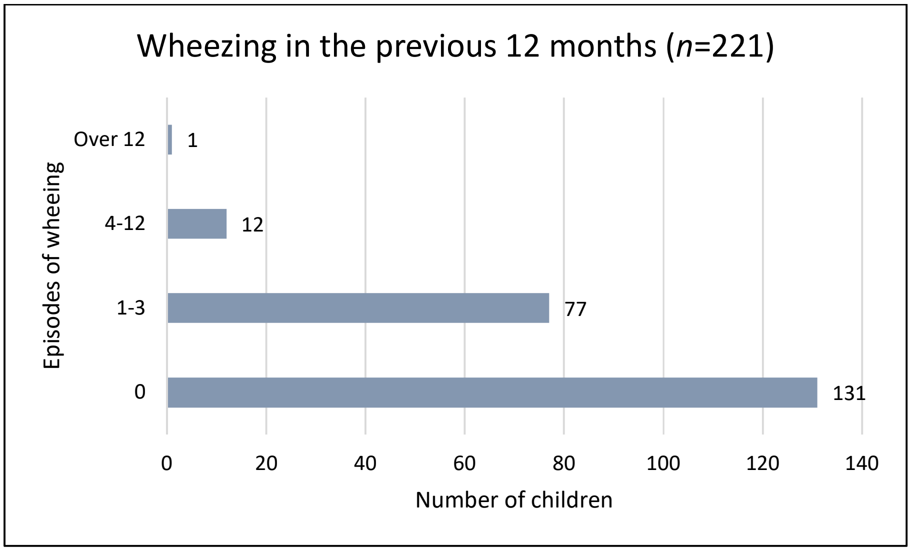
Most children (91%) had experienced colds in the 12 months prior to the study, with an average frequency of 3.1 episodes per child. 63% of children had at least one episode of vomiting (during the introductory phone call this was explained as vomiting likely to have been caused by infection), with a lower proportion (39%) experiencing diarrhoea.
After colds and gastrointestinal infections, the next most frequent illness type was ear infection, with 26% of children having experienced at least one ear infection.
For histograms of illness types see Appendix 14: Prior illness frequency histograms.

Table 14: Child illness frequencies during the 12 months prior to the commencement of the study

	Number of children						
Count of illnesses	Colds	Ear	Chest	Influenza-like illness	Diarrhoea	Vomiting	Croup
0	20	163	177	178	134	82	193
1	29	32	26	19	44	78	15
2	51	16	9	11	25	47	8
3	48	5	6	7	9	9	2
4	32	2	1	3	4	1	1
5	13	2	2	3	3	2	2
6	12	1			1	1	
7	1						
8	5						
9	1						
10	6						
11							
12	2				1	1	
13							
14							
15	1						
>0	201	58	44	43	87	139	28
>0 (%)	91%	26%	20%	19%	39%	63%	13%

Parents also provided data on their child's history of wheezing and asthma. 41% of the children had experienced wheezing during the previous 12 months, and 45% had been provided with an asthma preventative (inhaler) at some point in their lifetime. 9% of parents said their child had been diagnosed with asthma and 21% said asthma was 'suspected' (Figure 37). Children aged under five years are not reliably able to perform lung-function testing, and many children with episodes of wheeze commencing under age five years will have transient wheeze and resolution of their symptoms by mid-childhood [217]. Consequently, it is common for medical practitioners to refrain from diagnosing asthma in children under five years old in New Zealand.

Figure 37: Prior history of parentally reported wheezing in the previous 12 months

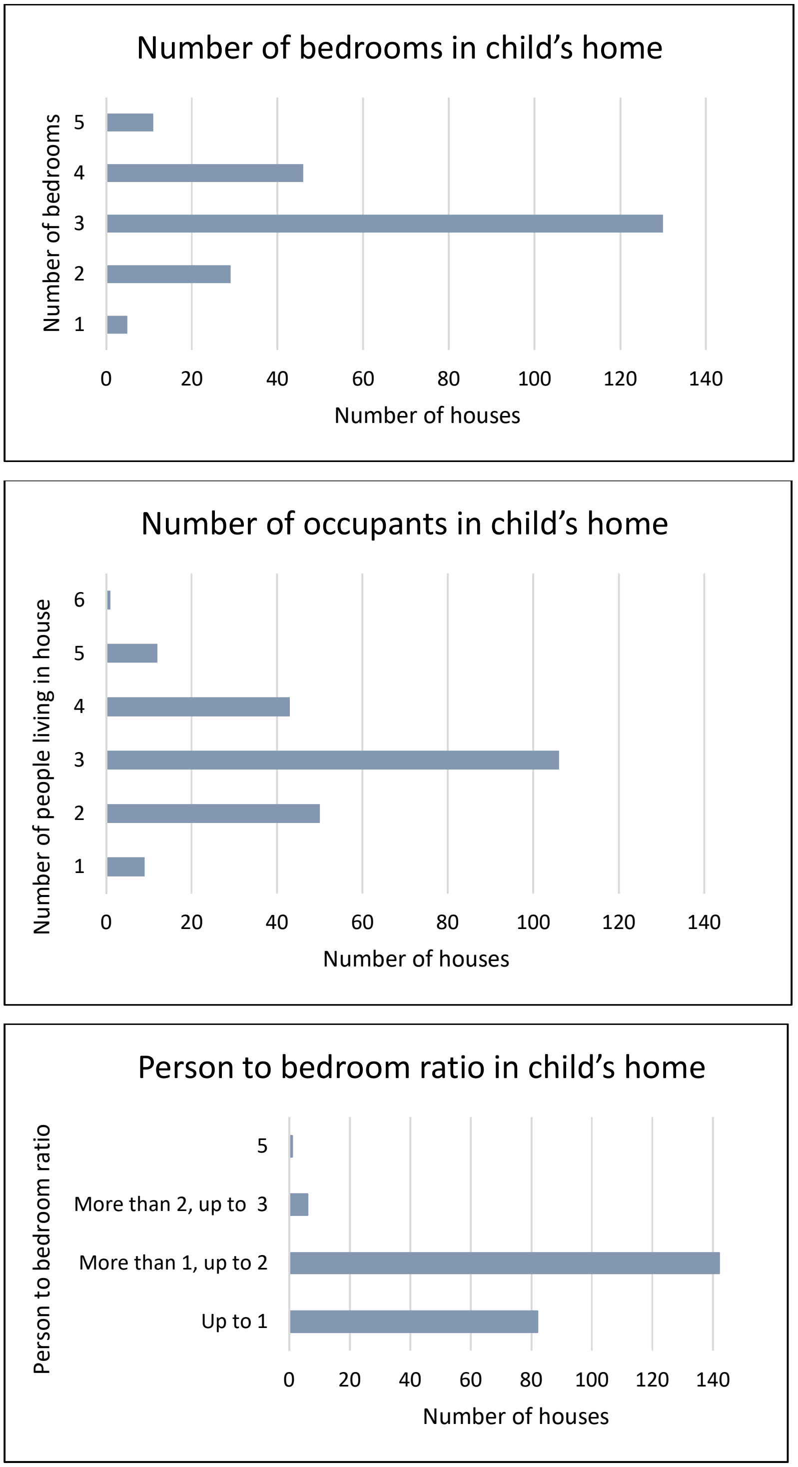


6.2.4 Child cohort home environments

Parent-reported home occupancy and crowding

Figure 38 shows the number of occupants and number of bedrooms in children's homes, with the ratio of occupants to bedrooms as an indicator of crowding. 37% of homes had no more than one person per bedroom, while 64% had more than one person but not more than two people per bedroom. Only seven homes (3.2%) had more than two people per bedroom.

Figure 38: Bedrooms and occupancy



Parent-reported coldness, dampness and mould in homes

About half of the respondents (49%) indicated that their homes were too cold during winter. A smaller proportion experienced shivering or could see their breath in the house sometimes or often (26% and 16% respectively) (see Figure 39). 20% reported that their house smelled damp or musty at times, and 29% reported mould in living areas, bedrooms or the kitchen (Figures 39 and 40).

Figure 39: Parents' assessments of coldness, damp and mould in homes

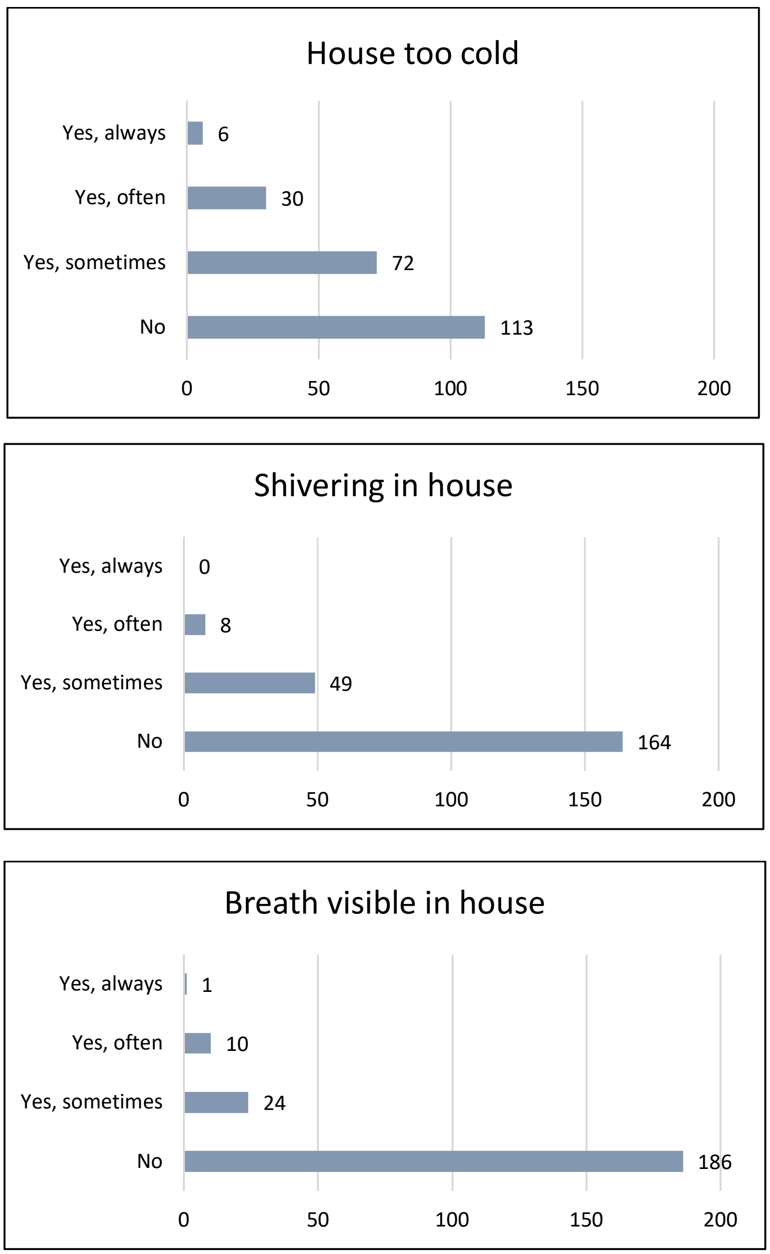
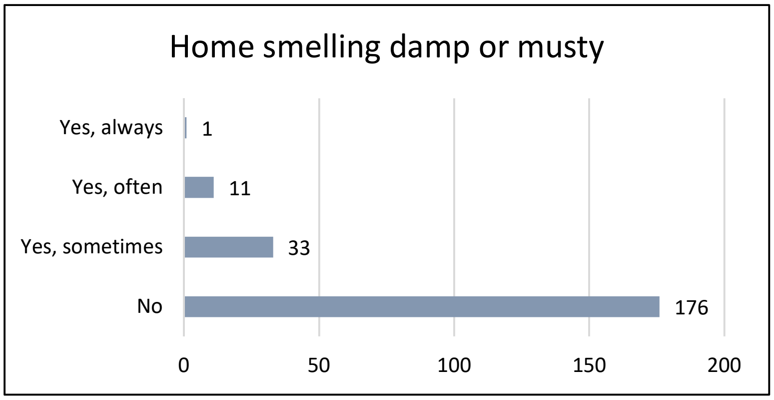
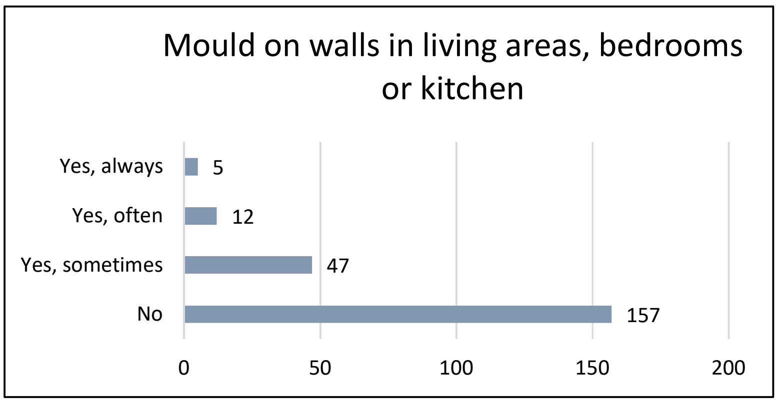


Figure 40: Dampness or mould in the home





Sibling attendance at an early childhood centre or school

38% of the enrolled children had one or more siblings attending an early childhood centre, and 44% had one or more siblings attending school. 66% of children had at least one sibling attending either an ECE centre or school.

Smoking in the home

Only one respondent said that a person smoked inside the house.

6.2.5 Childcare building, heating and ventilation characteristics

The centres in the study were all within the Ministry of Education category of ‘Education and Care Centres’, and were all full-day in their operation. Opening hours were from either 7:00 a.m. to 7:30 a.m. to either 5:30 p.m. or 6:00 p.m., with one exception that was open 8:00 a.m. to 4:30 p.m. The number of children in the centre environment (group size) ranged from 22 to 63, with a median of 30 (see Table 11).

The types of building were diverse, including seven ‘purpose-built’ centres, eight converted houses (including the centre for which temperature and humidity only were recorded), and seven converted industrial buildings. The converted houses were all of early to mid-20th-century wooden construction with weatherboard cladding, except for one which was built c1980–90 with brick veneer and wood construction. Outdoor areas ranged from spacious, with some grass, to minimal with no natural environment. All centres had free access to the outdoors for most of their operational hours.

All but five centres had some form of covered outdoor verandah space. Of the five that did not, two had indoor space open to outdoors that had been licensed as ‘outdoor space’.

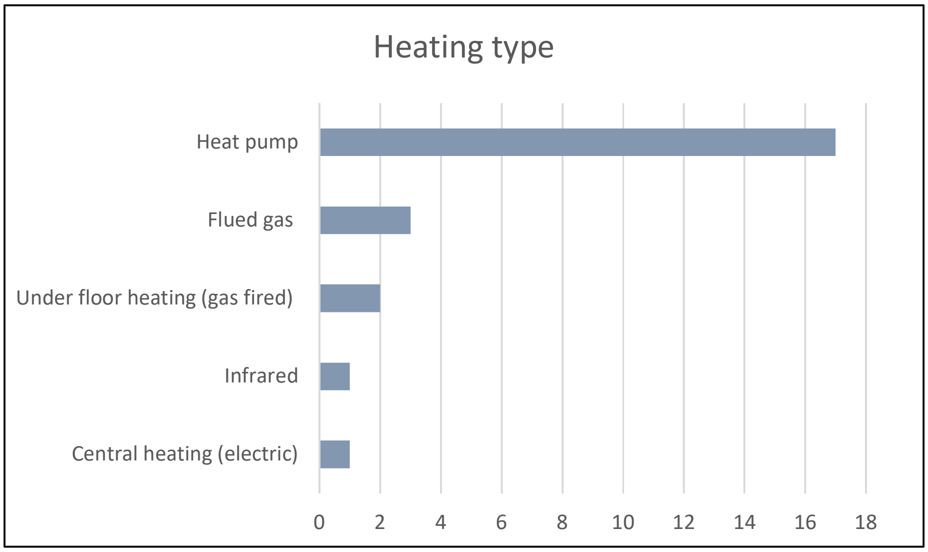
6.2.6 Childcare centre heating and ventilation

Heat pumps were by far the most common form of primary heating system, with 71% of centre environments using this system (See Figure 41). Centre managers were asked to comment on the effectiveness (did the system achieve the desired temperature?) and efficiency (was the cost of running the system reasonable for the system performance?) (Table 15).

Table 15: Heating system observations (Scale 1–5, from poor to excellent)

Environment number	Main heating system	Heating effective?	Heating efficient?	Manager's comments / researcher observations
1	Heat pump	4	Not known	
2	Central heating	2	Not known	On timer but sometimes not warm enough on cold mornings.
2.1	Heat pump	4	3	
3	Heat pump	4	4	
5	Gas – flued	5	4	
6	Underfloor heating (gas-fired)	5	Not known	
7	Heat pump	3	4	Not optimal arrangement of different heat pump locations and sizes.
8	Heat pump	4	Not known	Struggles to reach temperature if the door is open.
9	Heat pump	2	4	Poor performance on cold days.
10	Heat pump	3	4	Affected by open door.
11	Infrared	4	Not known	Diffuse infrared suspended panels.
12	Heat pump	4	3	Heat pump high-mounted next to outside door.
12.1	Heat pump	5	Not known	
13	Heat pump	5	5	Heat pump set to achieve 24°C but showing actual temperature as 19°C. Extra panel heater mounted at 1.2m above floor level.
15	Heat pump	4	Not known	
16	Gas – flued	5	5	
18	Heat pump	4	Not known	
19	Underfloor heating (gas-fired)	5	Not known	
20	Heat pump	1	1	Set to 22°C or 24°C to try to reach minimum temperature. Heat pump located at end of room opposite open door. Large air volume.
23	Heat pump	5	Not known	
25	Gas – flued	4	Not known	
28	Heat pump	5	5	
29	Heat pump	4	4	
30	Heat pump	5	Not known	

Figure 41: Childcare centre heating systems



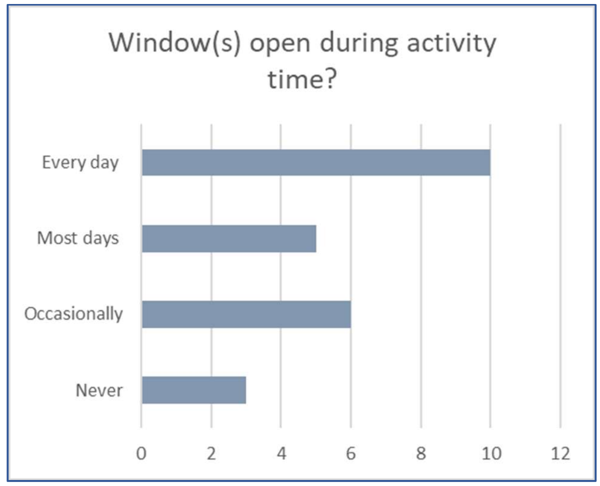
These assessments were subjective, and some centre managers were unable to answer the 'efficiency' question as they did not know the cost of running the system (payment was managed by someone else in the organisation).

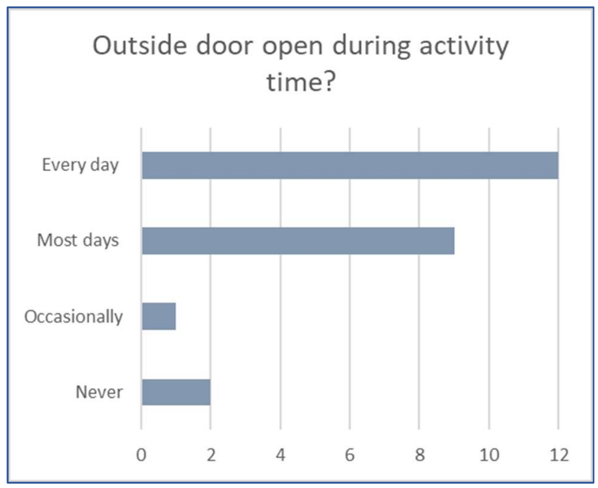
The heat pumps ranged in effectiveness rating from 1 (poor) to 5 (excellent) with an average score of 3.9. Two centres mentioned poor heat pump location, while in another that was described as struggling to meet the desired temperature, the heat pump was located at one end of a long, large room (17.3m long, $79m^2$).

Ventilation systems and reported use

Three of the 24 environments in the study had mechanical ventilation systems for their main activity areas. The remainder relied on windows and doors for ventilation. It was common practice for outside doors to be open during the day. For the environments that did not have windows reported to be open during the day, one manager described the outside doors as being open 'every day', and the other manager as open 'most days'. The remaining centre had an internal door normally open to what had previously been a vehicle garage, which was in turn open to outdoors.

Figure 42: Centre manager-reported ventilation using doors and windows





Of the managers of environments with sleep rooms that had opening windows, four said that sleep room windows were open ‘every day’, two ‘most days’, and three ‘occasionally’. None of the sleep rooms had passive ventilation such as door vents in addition to windows, except one that was open to a stairwell. One sleep room had mechanical ventilation that was found to be switched off after the CO_2 measurements had been taken.

Mould in childcare centres

None of the centres reported seeing visible mould, and none was seen in the in the researcher visits to the centres.

6.2.7 Childcare centre hygiene and sick child management

Handwashing and drying practices

Centre managers were asked about handwashing and drying practices, with the explanation, “This question is about what you think really happens, recognising that even when you try hard it can be difficult to be sure that children wash and dry hands when they should.” This was an appeal to provide an honest assessment of reality rather than a statement of best practice. These responses came from all 22 centres initially enrolled, representing 24 environments. Two environments did not perform nappy (diaper) change. Managers were asked to describe the frequency of hand hygiene actions. Table 16 shows the scoring system, with the maximum scores obtainable by totally scores across all centres.

Table 16: Hand hygiene descriptors and scoring

Action	
Child handwashing before eating	
Child handwashing after nose-blowing	
Child handwashing after toilet use	
Child handwashing after nappy (diaper) change	
Teacher handwashing after changing nappies (diapers)	
Child thorough hand-drying after handwashing	
Descriptor for frequency	**Score**
Always	5
Almost always	4
Usually	3
Sometimes	2
Rarely	1
Maximum possible scores for all environments	**Total Score**
Maximum score for 24 environments	120
Maximum score for 22 environments (nappy change)	110

Two measures were consistently good – child handwashing before eating, and teacher handwashing after changing nappies (diapers) (Table 17). Results for other practices showed considerable variation across environments. The worst combined scores were for handwashing after nose-blowing at 33%, with nine managers describing the frequency as ‘rarely’. Child handwashing after toilet use was 74%, but the score for child handwashing after nappy (diaper) change was 57%, with eight managers describing the frequency as ‘sometimes’ or ‘rarely’.

Table 17: Total scores for hand hygiene practice across all environments

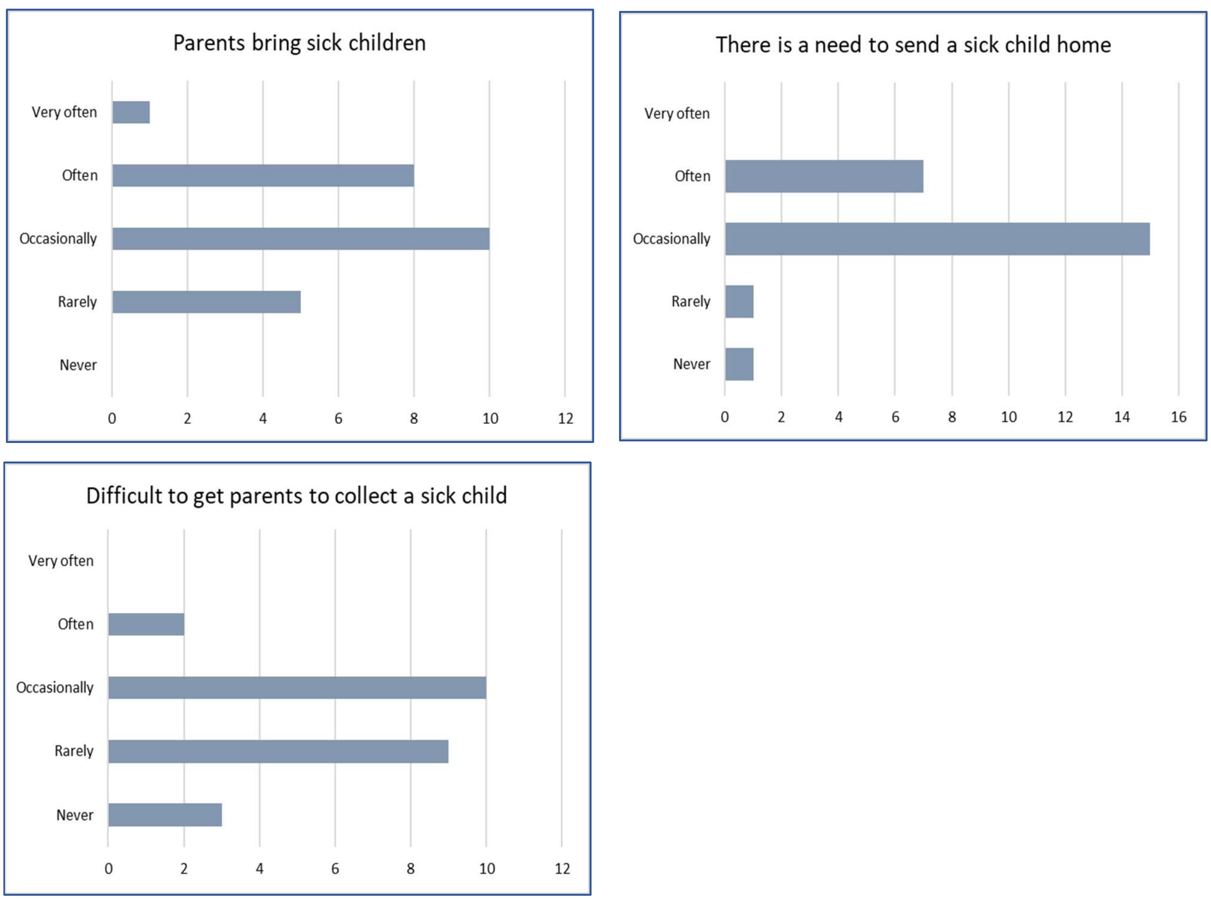
Action	Score	Percentage
Child handwashing before eating	117/120	98%
Child handwashing after nose-blowing	40/110	33%
Child handwashing after toilet use	89/120	74%
Child handwashing after nappy (diaper) change	68/110	57%
Teacher handwashing after changing nappies (diapers)	109/110	99%
Child thorough hand-drying after handwashing	79/120	66%

Cleaning practices

Cleaning practices varied considerably across the childcare centres, with combined cleaning scores for nappy-change area disinfection, table cleaning, toy washing and playdough use ranging from 20% to 100%. For example, disinfection of surfaces around the nappy change pad (as opposed to the pad itself) ranged from three to four times daily, to once in two or three weeks, while disinfection of objects around the pad ranged from 'twice daily' to 'not sure' or 'rarely'. Seven environments had shared soft toys ('comfort toys') and these were washed from 'once a week' to 'not often'. Fresh playdough was provided from once a day to once in two weeks.

Sick child exclusion

Figure 43: Sick child management



Nine of the twenty-two managers indicated that parents bringing a sick child to centre was a significant problem, stating that it happened 'often' or 'very often'. Overall scores for sick child management ranged from 25% to 75% (Figure 43).

6.3 Illnesses and absences

6.3.1 Illnesses and absences by individual child

The study recorded a total of 390 illness events, resulting in 1,715.5 sick days over 23 weeks (Table 19). This includes days when the child was sick at a weekend or days when they would not normally attend childcare. Total respiratory illnesses were the most frequent, accounting for 68% of illness events. Febrile illness accounted for 47% of events, while enteric illness (illnesses with any of vomiting, diarrhoea or stomach-ache) accounted for 27%. A chickenpox outbreak during the study affected several centres, accounting for 5% of illness events.

During the study it became apparent that there were differences in the thresholds for exclusion from centres due to illness. The manager of one centre, with relatively low numbers of children off sick, commented, "We have so many children with [high] temperatures and runny noses just now." The comment suggests that the centre had a higher threshold for exclusion, with more children attending sick and therefore having their illness not counted in the study as off sick. By contrast, the mother of one of the enrolled children complained that the exclusion policy of another centre was too restrictive: "They send them home if their temperature is half a degree above normal" (phone conversation with researcher).

Thirty-eight children had no days off sick. These children were on average 4.0 years of age, while those with at least one day of illness were on average 3.6 years of age. 79% of children with no illness had attended some form of ECE before two years of age, compared with 76% for those with at least one day of illness.

While respiratory infections were the most common at 265 events, they had one of the lower mean rates of days off per illness at 4.9 sick days per event. Due to the frequency of events they generated the largest numbers of days sick (76%), days away from childcare (71%), and parent days off work (71%). It is likely that some cases of chickenpox were not identified as such, but were counted in illnesses with fever or rash. Cases identified by parents as chickenpox resulted in the highest number of sick days per event (8.0), resulting in 12% of parent lost work days. Varicella vaccine (for chickenpox) was added to the New Zealand immunisation schedule in July 2017 [218], but this date was after the commencement of the ECEE study data collection period, and the vaccine is normally given at 15 months of age. Few, if any, children in the cohort would have received the vaccination. The category 'rash' will have included chickenpox cases, and it also included one child with a very high number of days off due to eczema.

6.3.2 Seasonal differences (Tables 18 –21)

There were fewer children in the study during spring than during winter, as some had left the study either because they turned five, or for other reasons such as family relocation. The spring season also had one less week of observation, so the combined effect was to reduce the number of spring child-weeks of attendance by 27% compared with winter.

The winter period generated 33% more child sick days per week; 38% more days lost from childcare per week; and 22% more parent lost work days and total illness events per week. The seasonal distributions of illness events and sick days by illness type were similar except for febrile illnesses. Febrile illnesses and respiratory illnesses with fever generated 56% and 50% of sick days respectively in winter, compared with 49% and 40% respectively in spring.

Table 18: Comparison of winter illness categories with spring illness categories

Seasonal difference by percentage point, (winter percentage - minus spring percentage)	Respiratory	Febrile	Respiratory and febrile	Enteric	Rash	Chickenpox	Ear infection	Respiratory and ear	Conjunctivitis
Percentage of child days sick - winter	76%	56%	50%	29%	9%	9%	9%	8%	3%
Percentage of child days sick - spring	75%	49%	40%	28%	13%	10%	4%	3%	7%
Percentage of child days sick - seasonal diffference	1%	7%	10%	1%	-4%	0%	4%	5%	-4%
Percentage of total illness events - winter	69%	48%	40%	27%	5%	5%	8%	6%	4%
Percentage of total illness events - spring	66%	47%	33%	27%	10%	6%	3%	1%	3%
Percentage of child days sick - seasonal difference	4%	1%	7%	0%	-5%	-2%	5%	4%	1%

Table 19: Child illnesses and absences, and parent absences from work (winter-spring)

	Children (winter -spring)	221									
	Child-observation weeks (winter-spring)	4745.3									
	Illness category	Total	Respiratory	Febrile	Respiratory and febrile	Enteric	Rash	Chickenpox	Ear infection	Respiratory and ear	Conjunctivitis
Count	Child days sick	1715.5	1303	915	793	489.5	173	160	124	103	80
	Day care days off	950.5	672.5	492	416	275	102	101	72.5	62.5	38
	Parent lost work days	650	460	390	332	192.5	79	57	54	42	16
	Count of events	390	265	184	145	104	26	20	25	16	15
Rate	Mean rate child days sick / week of attendance	0.36	0.27	0.19	0.17	0.10	0.04	0.03	0.03	0.02	0.017
	Mean rate child days off / week of attendance	0.20	0.14	0.10	0.09	0.06	0.02	0.02	0.02	0.01	0.008
	Mean rate parent days off / week of attendance	0.14	0.10	0.08	0.07	0.04	0.02	0.01	0.01	0.01	0.003
	Mean rate events / week of attendance	0.08	0.06	0.04	0.03	0.02	0.01	0.00	0.01	0.00	0.003
	Mean rate days sick / event	4.4	4.9	5.0	5.5	4.7	6.7	8.0	5.0	6.4	5.3
Percentage of total	Percentage of child days sick	100%	76%	53%	46%	29%	10%	9%	7%	6%	5%
	Percentage of day care days off	100%	71%	52%	44%	29%	11%	11%	8%	7%	4%
	Percentage of parent lost work days	100%	71%	60%	51%	30%	12%	9%	8%	6%	2%
	Percentage of total illness events	100%	68%	47%	37%	27%	7%	5%	6%	4%	4%

Table 20: Child illnesses and absences, and parent absences from work (winter only)

	Children (winter)	220									
	Child-observation weeks (winter)	2536.2									
	Illness category	Total	Respiratory	Febrile	Respiratory and febrile	Enteric	Rash	Chickenpox	Ear infection	Respiratory and ear	Conjunctivitis
Count	Child days sick	1105.5	843.5	615.5	551.5	319	96	102	97	85	35
	Day care days off	636	457.5	334	296.5	189	63	64	60	54	21
	Parent lost work days	406	298.5	252	228.5	129	47	24	41	34	14
	Count of events	244	169	116	97	65	12	11	20	14	10
Rate	Mean rate child days sick / week of attendance	0.44	0.33	0.24	0.22	0.13	0.04	0.040	0.038	0.034	0.014
	Mean rate child days off / week of attendance	0.25	0.18	0.13	0.12	0.07	0.02	0.025	0.024	0.021	0.008
	Mean rate parent days off / week of attendance	0.16	0.12	0.10	0.09	0.05	0.02	0.009	0.016	0.013	0.006
	Mean rate events / week of attendance	0.10	0.07	0.05	0.04	0.03	0.00	0.004	0.008	0.006	0.004
	Mean rate days sick / event	4.5	5.0	5.3	5.7	4.9	8.0	9.3	4.9	6.1	3.5
Percentage of total	Percentage of child days sick	100%	76%	56%	50%	29%	9%	9%	9%	8%	3%
	Percentage of day care days off	100%	72%	53%	47%	30%	10%	10%	9%	8%	3%
	Percentage of parent lost work days	100%	74%	62%	56%	32%	12%	6%	10%	8%	3%
	Percentage of total illness events	100%	69%	48%	40%	27%	5%	5%	8%	6%	4%

Table 21: Child illnesses and absences, and parent absences from work (spring only)

	Children (spring)	183									
	Child-observation weeks (spring)	1857.4									
	Illness category	Total	Rspiratory	Febrile	Respiratory and febrile	Enteric	Rash	Chickenpox	Ear infection	Respiratory and ear	Conjunctivitis
Count	Child days sick	610	459.5	299.5	241.5	171	77	58	27	18	45
	Day care days off	314.5	215	158	119.5	86	39	37	12.5	8.5	17
	Parent lost work days	244	161.5	138	103.5	63.5	32	33	13	8	2
	Count of events	146	96	68	48	39	14	9	5	2	5
Rate	Mean rate child days sick / week of attendance	0.33	0.25	0.16	0.13	0.09	0.04	0.031	0.015	0.010	0.024
	Mean rate child days off / week of attendance	0.17	0.12	0.09	0.06	0.05	0.02	0.020	0.007	0.005	0.009
	Mean rate parent days off / week of attendance	0.13	0.09	0.07	0.06	0.03	0.02	0.018	0.007	0.004	0.001
	Mean rate events / week of attendance	0.08	0.05	0.04	0.03	0.02	0.01	0.005	0.003	0.001	0.003
	Mean rate days sick / event	4.2	4.8	4.4	5.0	4.4	5.5	6.4	5.4	9.0	9.0
Percentage of total	Percentage of child days sick	100%	75%	49%	40%	28%	13%	10%	4%	3%	7%
	Percentage of day care days off	100%	68%	50%	38%	27%	12%	12%	4%	3%	5%
	Percentage of parent lost work days	100%	66%	57%	42%	26%	13%	14%	5%	3%	1%
	Percentage of total illness events	100%	66%	47%	33%	27%	10%	6%	3%	1%	3%

6.3.3 Child and parent illnesses and absence outcomes as days per week of attendance

Table 22 shows the impact of illnesses and absences against weeks of attendance over the winter-spring period. The data indicates that, on average, a child would have about four days off childcare during winter-spring, and parents could expect an average of about three days leave from work during that time. These figures are only averages, however, and the parent cohort would have included some parents with flexible care arrangements (e.g. partner or other caregivers available), while others might have been dependent on sick leave to care for their sick child. The number also included children who were not sick at all. For parents who reported that they lost work time, the average loss was one day per 4.8 weeks (about 5.5 days per winter-spring half-year), with a median of one day per 5.9 weeks (about 4.5 days per winter-spring half year).

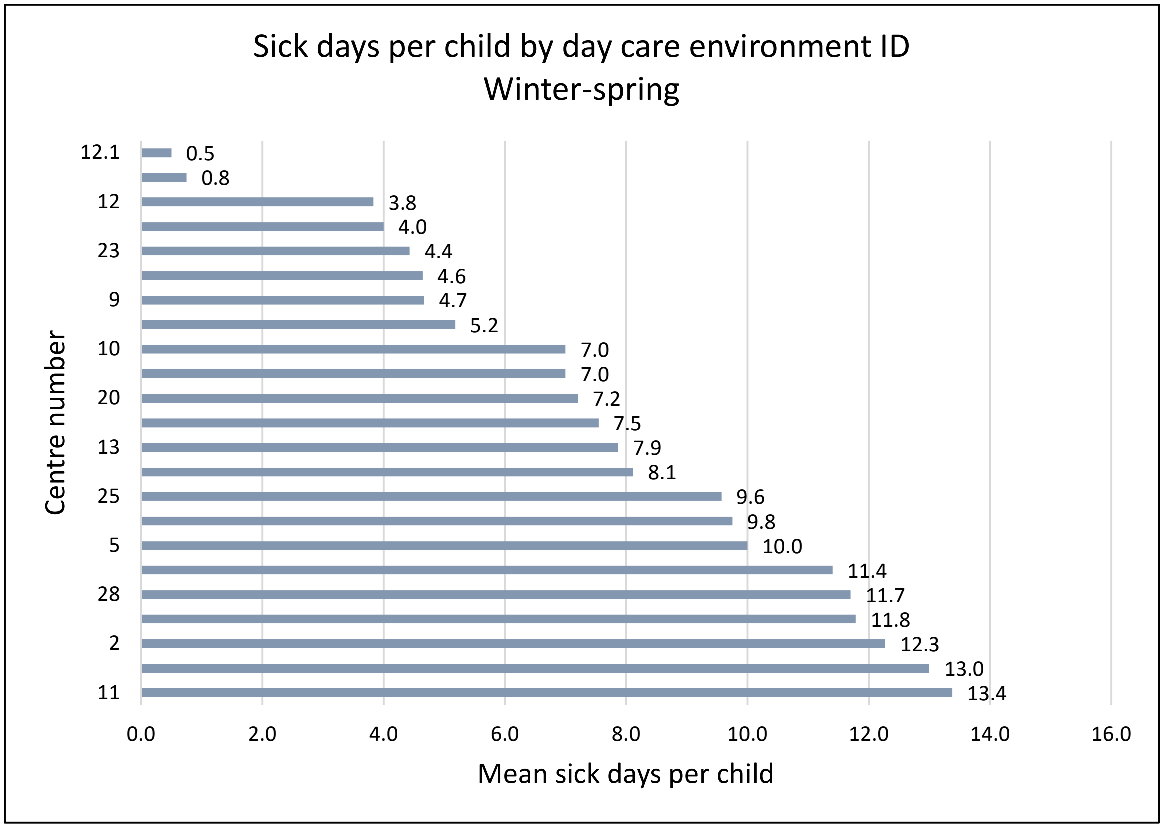
Table 22: Impact of illnesses in days per week

Child days sick	Average one day per 2.7 weeks	
Day care days off	Average one day per 5.0 weeks	Lost work per winter-spring half year
Parent lost work days (all parents)	Average one day per 7.3 weeks	
Parent lost work days if any time lost	Average one day per 4.8 weeks	5.4 days
Parent lost work days if any time lost	Median one day per 5.9 weeks	4.4 days

6.3.4 Illness rates by childcare centre

There was a very wide range of mean days of illness per child by childcare centre, from 0.5 to 13.4 days (Figure 44). While Environment 12.1 with 0.5 sick days per child had the oldest age-group in the study, age-group did not explain the other variances in the distribution. The second-oldest group was in Environment 2, with a mean of 12.3 sick days per child.

Figure 44: Sick days per child by childcare environment ID during winter-spring study period



6.4 Childcare environmental conditions

6.4.1 Area per child results

The study found that ten out of twenty-three environments (nine out of twenty-one centres) breached the minimum regulations for space per child ($2.5m^2$) at least 10% of the time, and up to a maximum of 85.9% of the time. Four centre environments (from three centres) were operated at times below $2.0m^2$ per child (Table 23).

Environments 5, 9, 12, and 12.1 each had a median area per child below $2.5m^2$ per child (see Table 24). The study found that environments 5, 12, and 12.1 had been incorrectly licensed by the Ministry of Education, with a licence for a larger number of children than the space could legally accommodate. In the case of environment 5, the owners could show the researcher the plan used by the Ministry of Education to calculate licence capacity. The plan showed that corridor space had been licensed as activity space, in contravention of the regulations. Across the centres space per child varied considerably, with median space per child ranging from 2.23 to 4.35m^2 per child.

Table 23: Legal compliance and percentage of time by area per child threshold

ECEE Environment No.	Net area m^2	% < 2.0	% < 2.5	% < 3.0	% < 3.5
20	152.25	0.0%	0.0%	0.0%	2.6%
16	96.85	0.0%	0.0%	0.0%	4.3%
2	77.66	0.0%	0.0%	0.0%	7.0%
18	124.03	0.0%	0.0%	0.0%	6.1%
23	173.82	0.0%	0.0%	4.4%	43.0%
10	72.01	0.0%	0.0%	8.8%	74.3%
8	82.93	0.0%	0.0%	10.5%	60.5%
15	111.98	0.0%	0.0%	17.5%	73.7%
3	77.97	0.0%	0.0%	20.4%	62.8%
1	142.02	0.0%	2.6%	55.3%	91.2%
25	83.21	0.0%	2.6%	59.6%	84.2%
28	60.86	0.0%	2.6%	61.4%	88.6%
19	115.04	0.0%	7.0%	76.3%	97.4%
11	71.79	0.0%	11.0%	74.3%	94.5%
6	93.82	0.0%	12.3%	80.7%	94.7%
30	130.01	0.0%	15.8%	87.7%	96.5%
29	51.86	0.0%	33.3%	72.8%	93.9%
2.1	69.76	1.8%	33.3%	80.7%	98.2%
13	44.27	0.0%	43.0%	84.2%	96.5%
12	30.12	8.8%	50.0%	81.6%	97.4%
5	60.99	4.4%	68.4%	96.5%	100.0%
9	61.89	0.9%	70.2%	98.2%	100.0%
12.1	64.55	22.8%	89.5%	100.0%	100.0%

Table 24: Space allocation by quartile

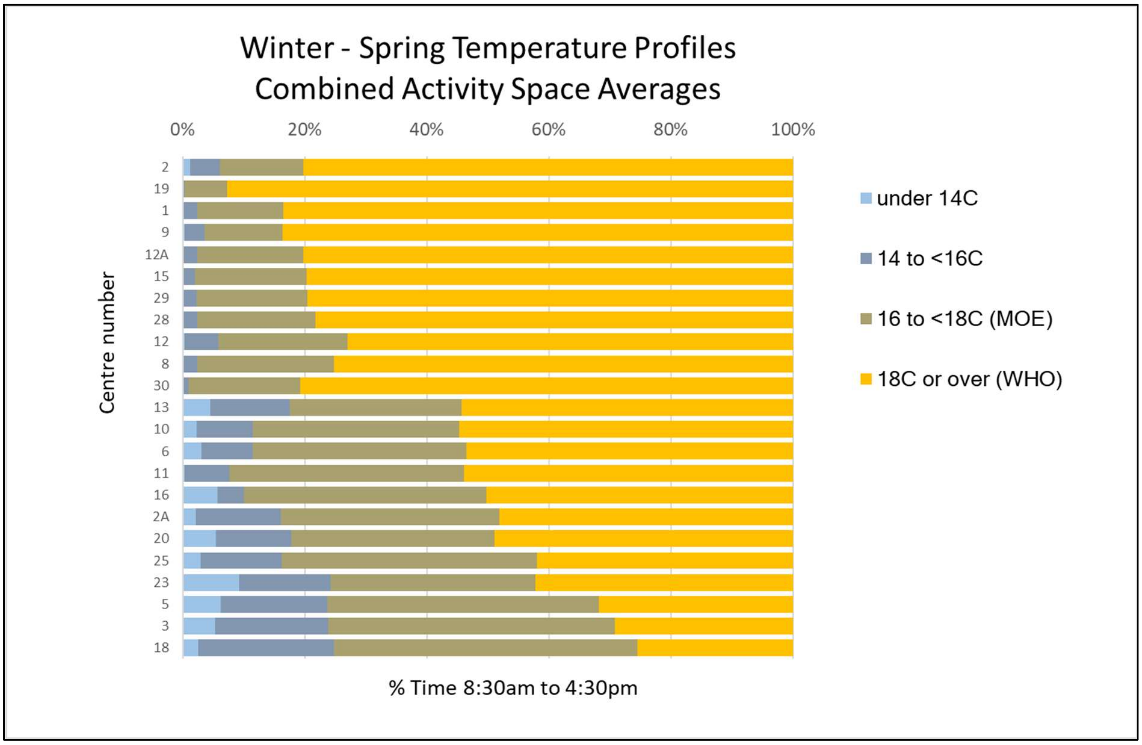
ECEE Environment No.	Min	25th percentile	Median	75th percentile	Max
20	3.31	4.01	4.35	4.91	7.25
16	3.23	4.04	4.21	4.84	6.46
2	3.11	3.88	4.09	4.57	8.63
18	3.26	3.65	3.76	4.13	7.30
23	2.85	3.34	3.62	4.04	5.79
8	2.76	3.07	3.46	3.77	6.91
15	2.67	3.11	3.39	3.61	4.00
3	2.60	3.12	3.39	3.54	4.59
10	2.67	3.13	3.27	3.60	4.50
25	2.31	2.77	2.97	3.20	5.94
1	2.45	2.78	2.96	3.30	4.73
28	2.43	2.77	2.90	3.20	4.68
11	2.39	2.66	2.76	3.12	4.22
19	2.30	2.61	2.74	2.95	3.71
30	2.28	2.55	2.74	2.89	4.19
29	2.07	2.47	2.73	3.05	4.71
2.1	1.94	2.41	2.68	2.91	3.88
6	2.41	2.61	2.68	2.93	4.69
13	2.11	2.46	2.60	2.95	4.43
12	1.77	2.15	2.41	2.74	4.30
9	2.00	2.29	2.38	2.58	3.44
5	1.91	2.18	2.26	2.54	3.21
12.1	1.70	2.02	2.23	2.39	2.81

6.4.2 Temperature results

Indoor temperatures in childcare centres

The analysis of room temperatures and humidity required consideration of the complexities of room use and the variability of building layout. Room layout in the study ranged from a single activity and sleeping space to centres with four or five activity spaces. Tag allocation had reflected these differences, with deployment of only one Tag in some centres and up to five in others. Tag data were averaged over the Tags that were located in spaces that were generally in use for activities. Dedicated sleep rooms were not counted in the data, as they were for short-term use and subject to temperature fluctuations during the day not experienced by the children.

Figure 45: Seasonal temperature profiles averaged across activity spaces



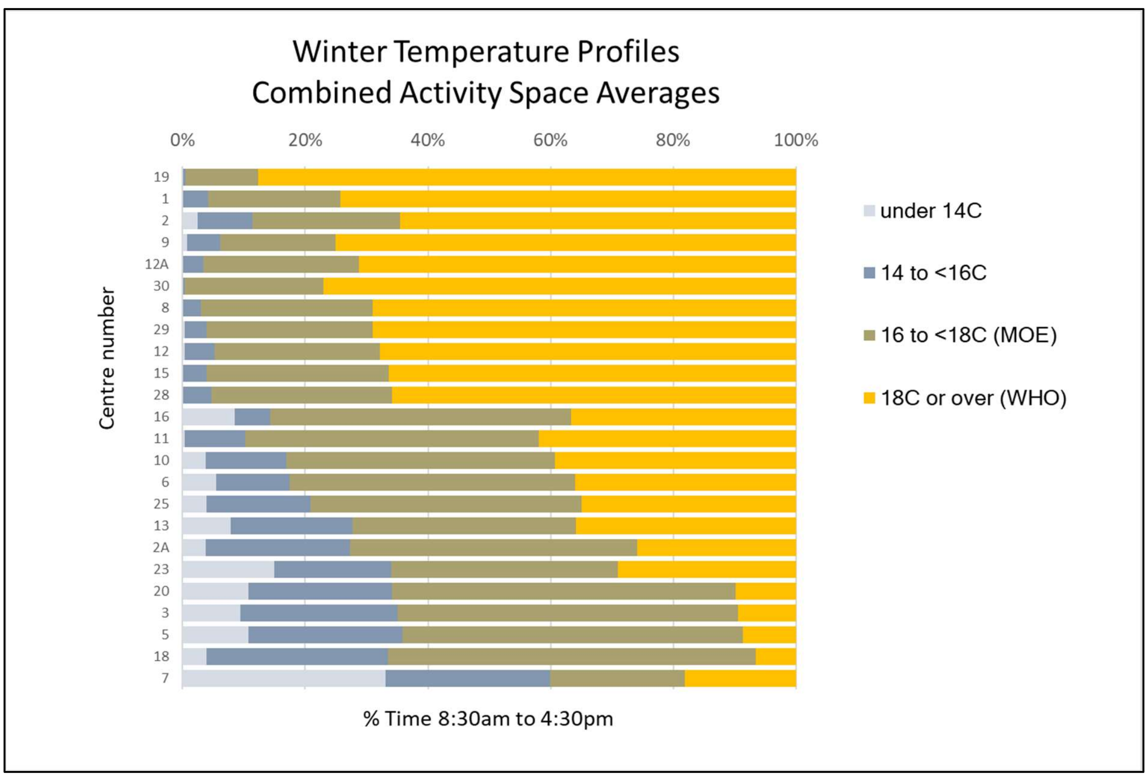
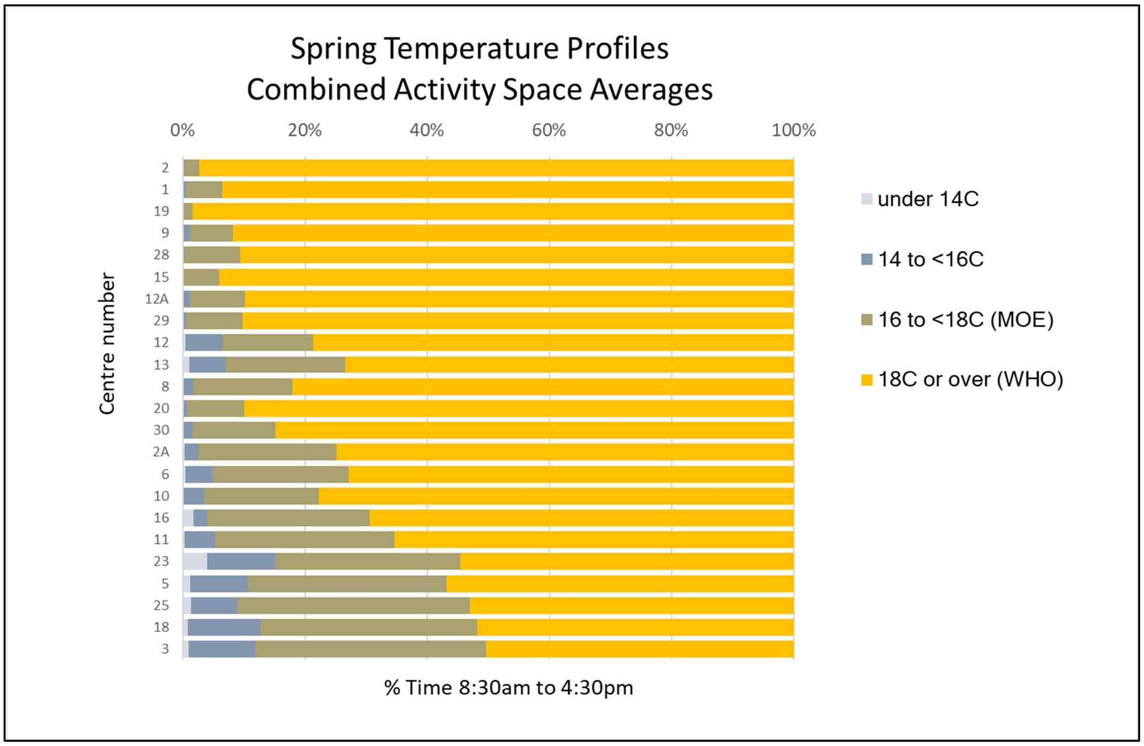


Figure 46 (continued): Seasonal temperature profiles averaged across activity spaces



The study found that during the winter season, 90% of centres were breaching the 16ºC minimum temperature set by regulation for at least some of their operational time. 67% were operating below 16ºC for between 10% and 36% of the time their centres were open (between 8:30 a.m. and 4:30 p.m.), and one centre was below 16ºC for 60% of the time. These measurements, as shown in Figure 46, were taken at least 30 minutes inside the limits of the centre's operational time, so that 'warm-up' time would not be counted. For most centres the data were from 1½ hours after starting time.

During winter the indoor median temperatures of the centres ranged from 15.3ºC to 19.9ºC (mean 17.9ºC), while in spring median temperatures ranged from 18.0ºC to 21.2ºC (mean 19.3ºC).

Outdoor temperatures and rainfall

Outdoor temperature and rainfall raw data were received from the New Zealand Meteorological Service, from monitoring stations in Lower Hutt and Wainuiomata. No data for these measurements were available for Johnsonville-Newlands or Upper Hutt. The data provide an indication of outdoor conditions, relevant to the heating demands on childcare centres, and the ability of children to spend time outdoors.

Table 25: Lower Hutt and Wainuomata winter and spring temperatures (^oC).

		Lower Hutt	Wainuiomata
Winter temperatures	Minimum	1.0	-1.5
	25th percentile	9.0	9.6
	Median	10.8	12.2
	75th percentile	13.0	14.1
	Maximum	16.8	17.7
Spring temperatures	Minimum	5.2	2.3
	25th percentile	13.5	13.6
	Median	15.6	15.3
	75th percentile	18.2	17.8
	Maximum	23.5	24.0

Table 25 shows that, at times, the lowest temperatures in winter were around freezing point, with temperatures below 10^{o}C for about a quarter of the time.

Winter 2017 in region was quite wet, based on Lower Hutt data, while late spring was relatively dry. While no data for rainfall was available for Upper Hutt or Newlands, the variation will not have been as great as the temperature differences between these locations. Dry weekdays during the study period are shown in Table 26.

Table 26: Dry weekdays during the study period

	Dry days	Total days	% dry days
June	9	15	60%
July	10	21	48%
August	7	23	30%
September	9	21	43%
October	15	21	71%
November	12	13	92%

July weather included heavy rainfall, with one period of four days having 75.4mm of rain. By contrast, October and November together had just two weekdays with more than 1mm of rain per day, and a total of 12.6mm over 34 weekdays.

6.4.3 Relative humidity results

Indoor relative humidity data showed little overall variation across the winter-spring seasons. Indoor winter median relative humidity was in the range 53% to 71%, while the spring equivalent values were a little drier at 47% to 68% (Figures 47 and 48). There were some high humidity values at times, however, and in the centre with highest average indoor humidity there was a large difference between two of the rooms. These rooms were connected by an open space without doors, but while the main activity space was frequently open to the outside, the quiet room / sleep room had openable windows but no outside door (Figure 46).

Figure 46: Difference in relative humidity in connected rooms

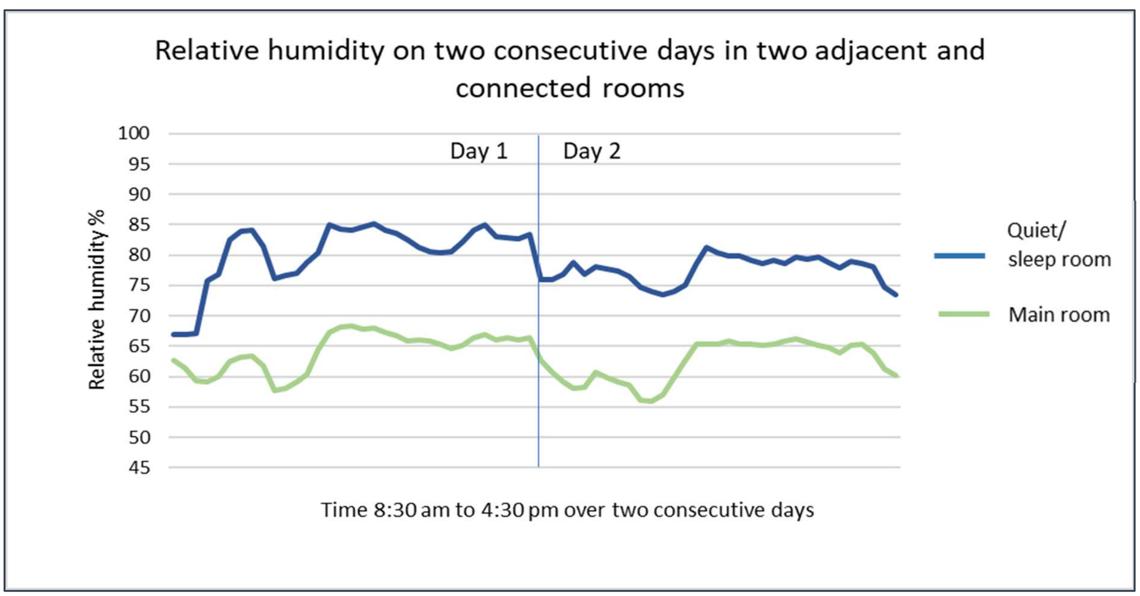
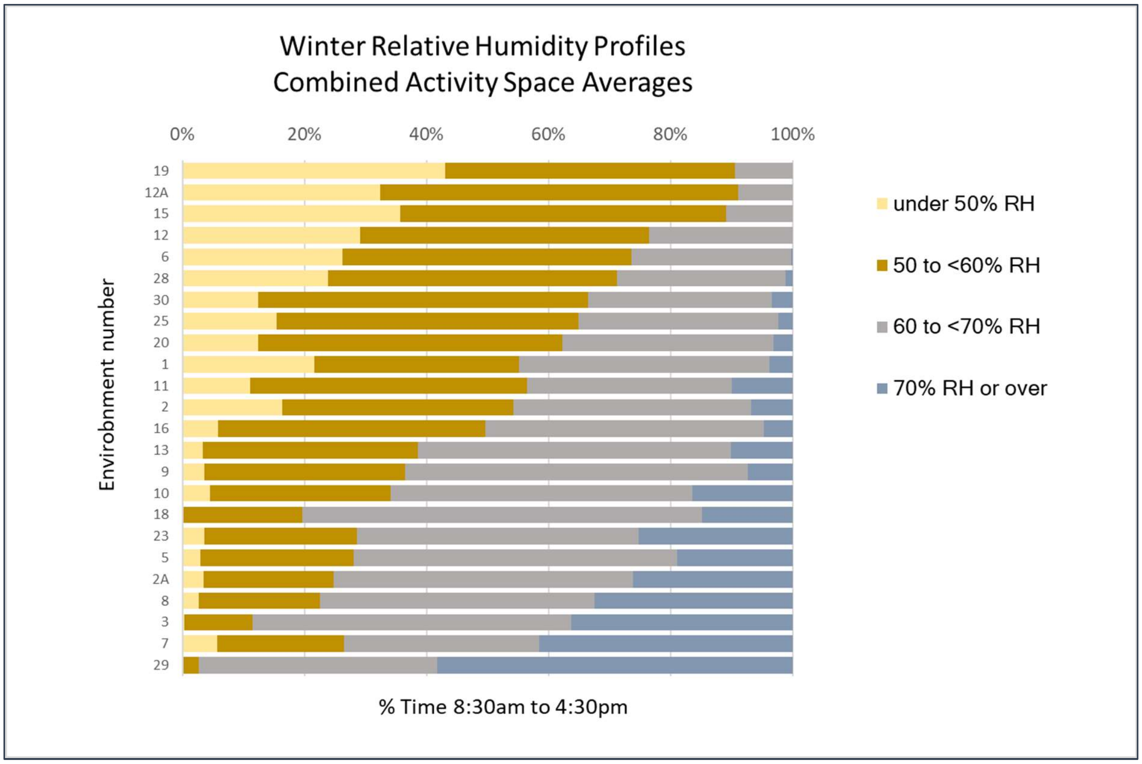


Figure 47: Seasonal relative humidity profiles by humidity band averaged across activity spaces



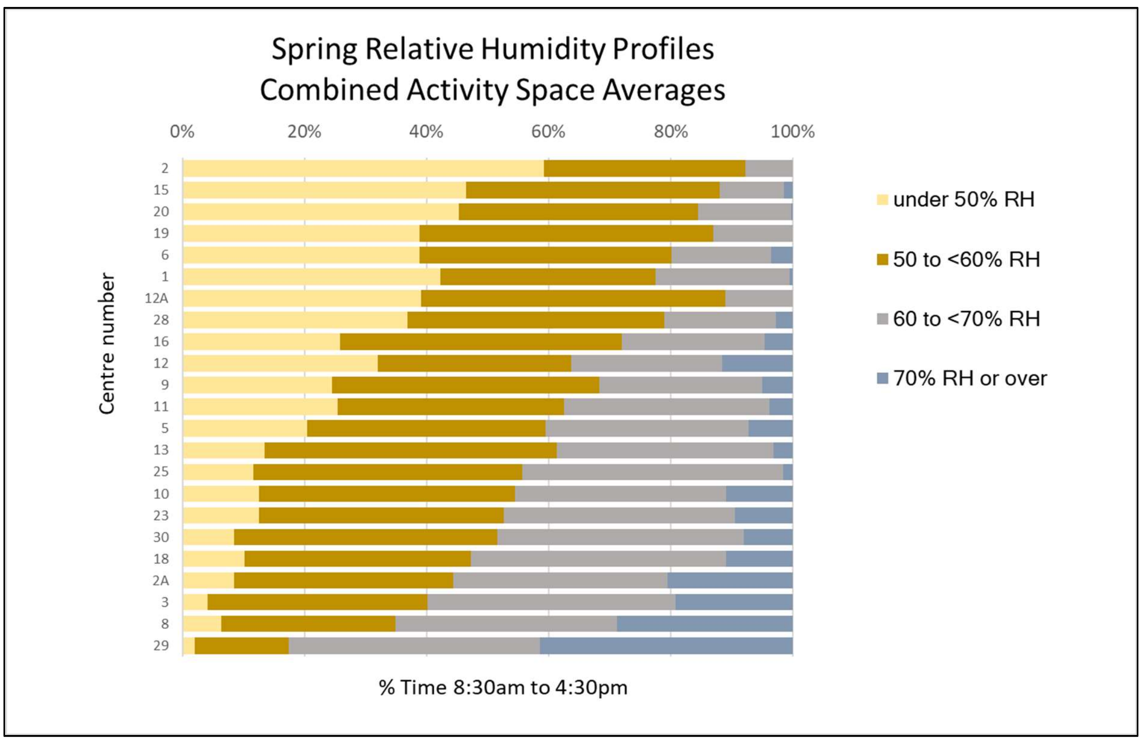
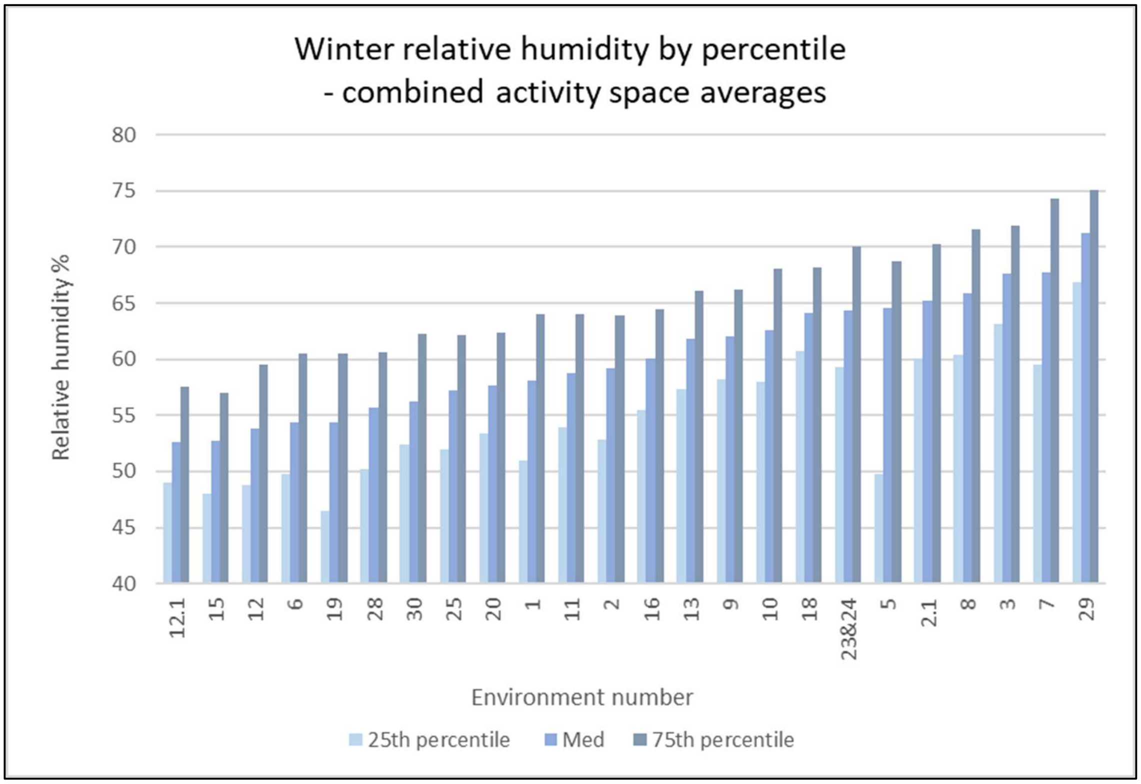
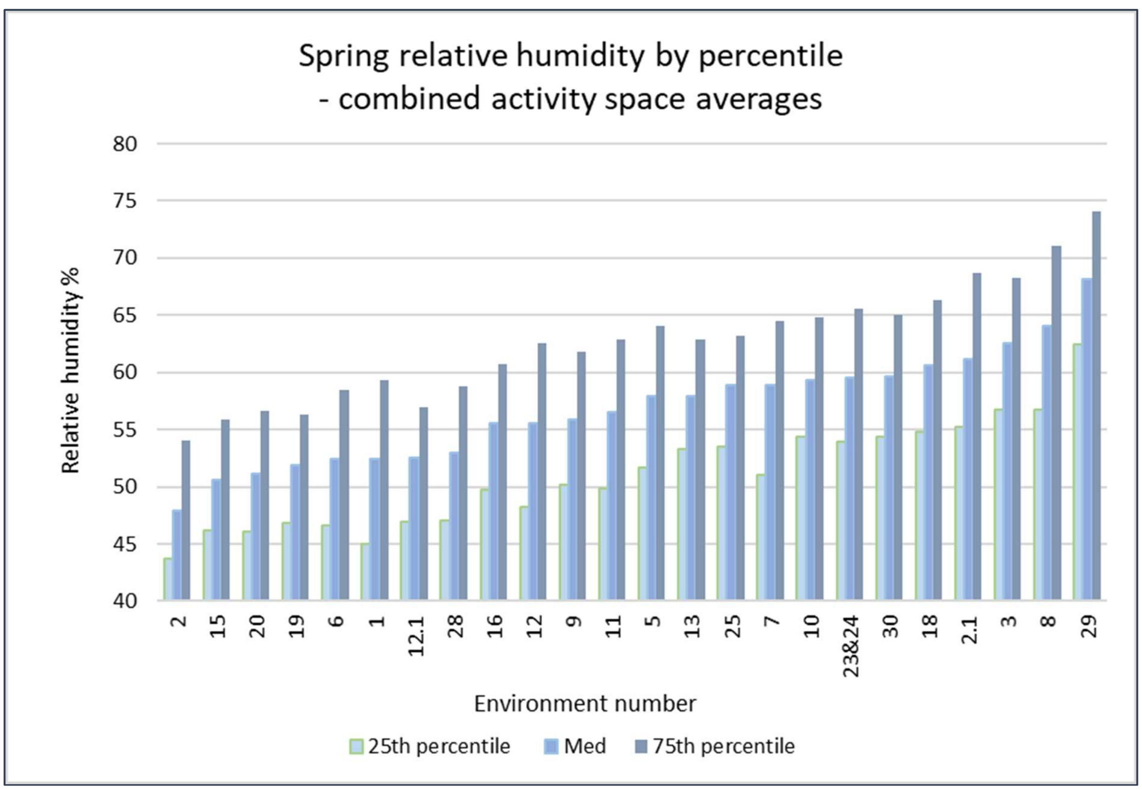


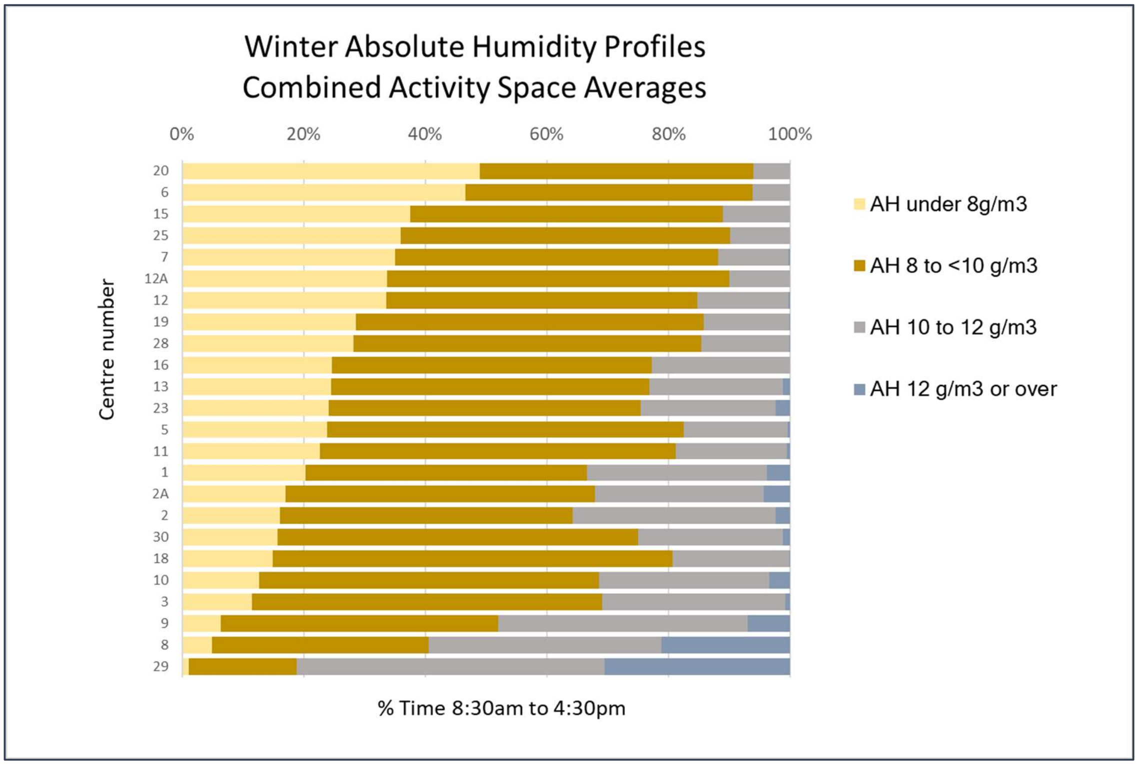
Figure 48: Seasonal indoor relative humidity by quartile averaged across activity spaces

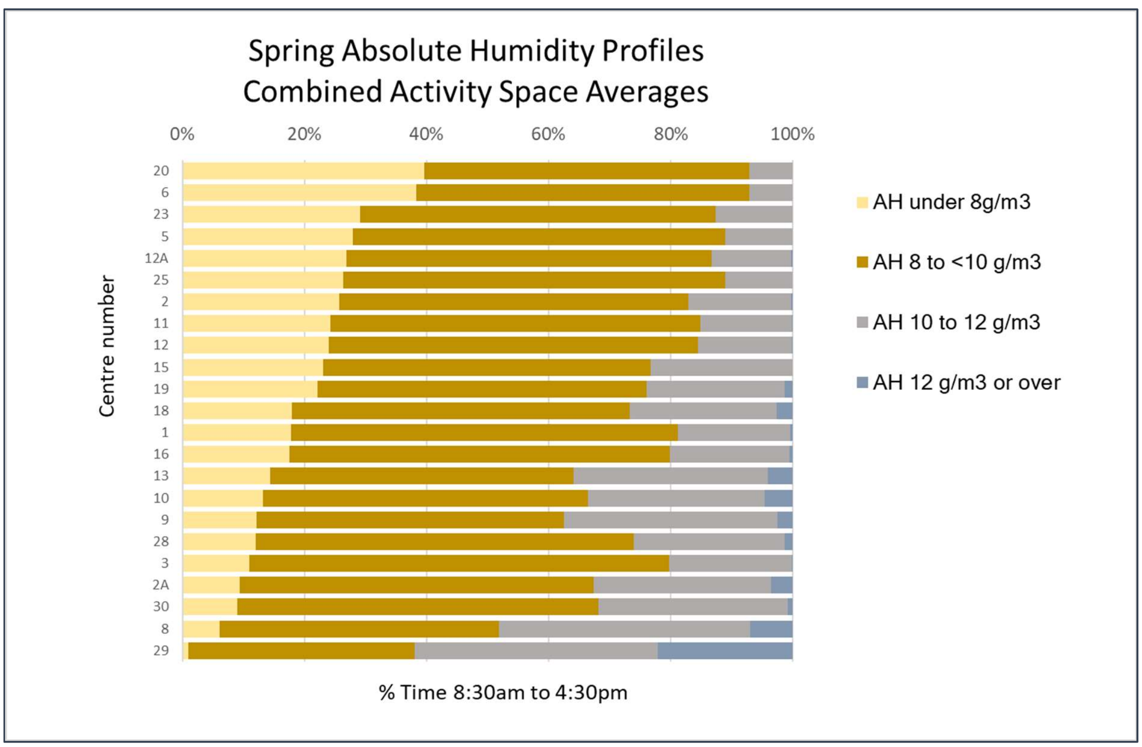




6.4.4 Absolute humidity results

Figure 49: Seasonal absolute humidity profiles by humidity band averaged across activity spaces





Absolute humidity also showed little variation between winter and spring, but spring had slightly higher values. Median values ranged from 8.0g (H_2O)/m^3 to 11.3g H_2O/m^3 in winter, and from 8.7g (H_2O)/m^3 to 11.7g (H_2O)/m^3 in spring (Figure 49)).

6.4.5 CO_2 measurements

CO_2 measurements were taken in 13 sleep rooms, and showed some very high levels while sleep rooms were in use (see Section 3.3.4 for BRANZ recommendation for classroom CO_2 levels). Six sleep rooms had levels exceeding 3,000ppm, with the highest level being 3,792ppm. Another two exceeded 2,000ppm. Only one had levels consistently below 1,000ppm. CO_2 levels were measured in spring, during which time two centres (centre number 8 and centre number 29) had 75th percentile levels above 70%, which can affect the HOBO monitor accuracy. CO_2 levels were not recorded in either of these centres as they did not have dedicated sleep rooms.

Figure 50 shows an example of sharp increases and declines in sleep room CO_2 over four days, for two of the centres. The peaks after midday coincide with after-lunch sleep times.

Figure 50: CO_2 levels in sleep rooms

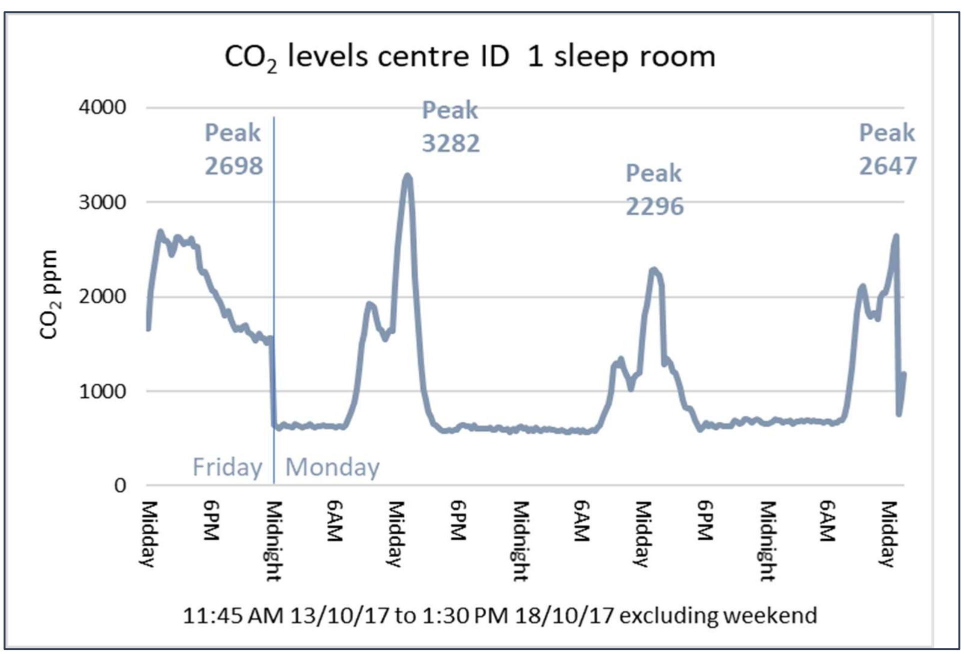
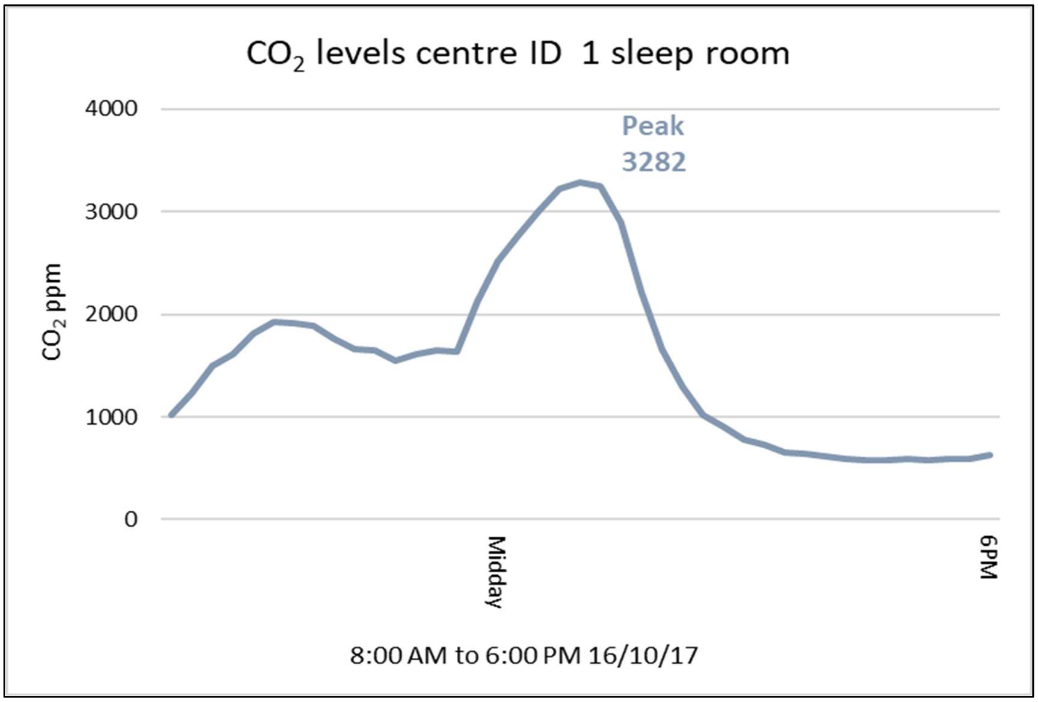
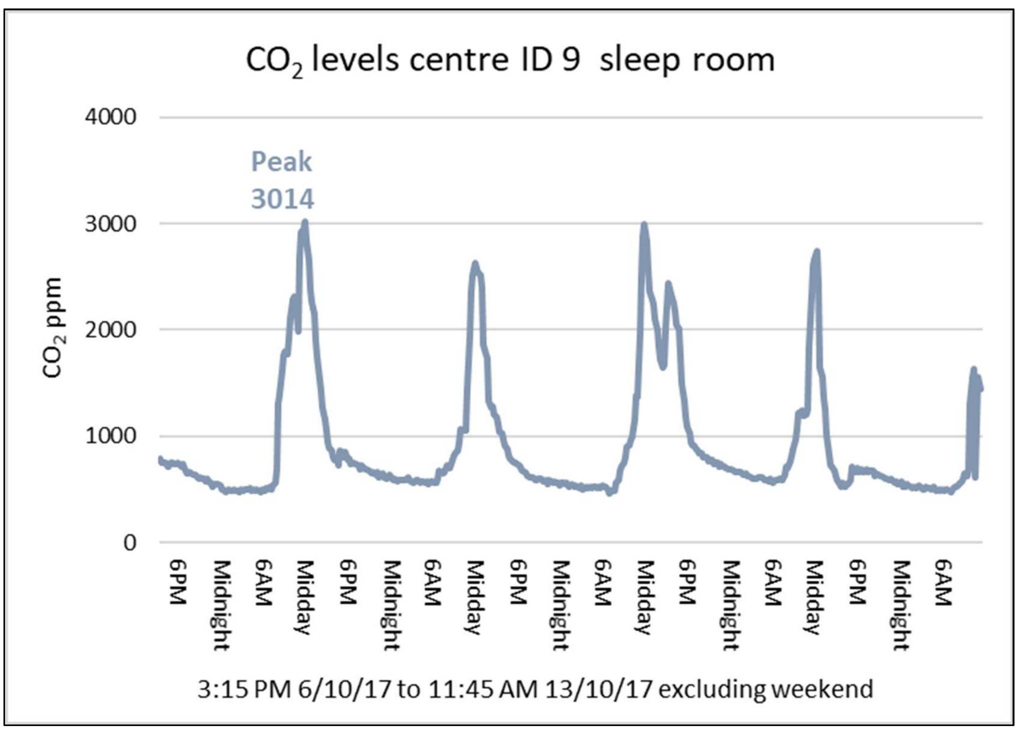


Figure 50 (continued): CO_2 levels in sleep rooms

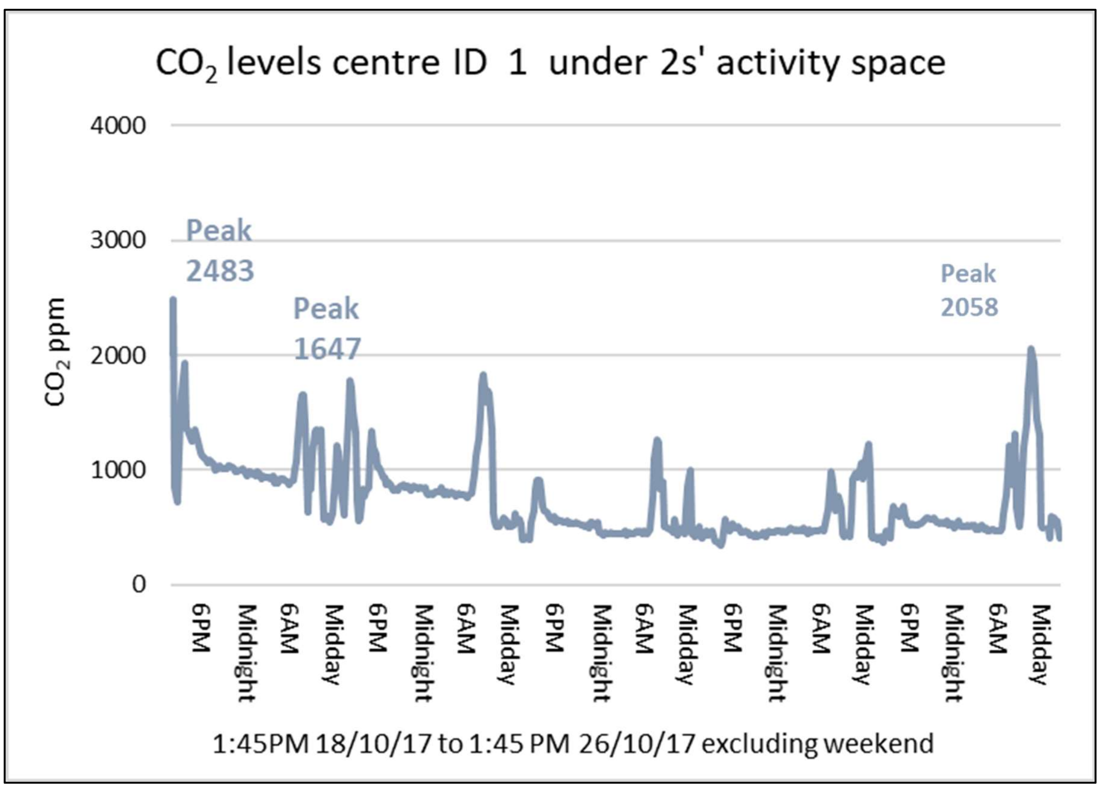




The sleep room in Environment 1 had no passive ventilation other than windows. In the Phase One questionnaire, the manager of the centre said that these windows were opened "occasionally" when the room was in use. The sleep room in Environment 9 had no windows, and no other passive ventilation.

While not part of the ECEE study scope, measurements were also taken in an activity space for children under two years old in Environment 1 for seven days, as the air quality seemed stuffy (researcher observation), and the staff believed that the heat pump provided ventilation. While not as high as some of the sleep room CO_2 levels days, CO_2 exceeded 1,200ppm on every day of use, with two peaks over 2,000ppm (Figure 51).

Figure 51: CO_2 levels in an activity space for children under two years old



6.5 Correlation of illness rates with environmental conditions

6.5.1 Univariate analysis of child and environmental covariates – screening for inclusion in a generalised linear model

As a preliminary step in developing a generalised linear mixed model (GLMM) analysis, all variables were analysed with univariate regression (see Section 5.6.6). For centre covariates, correlations showed greater statistical significance when winter data was used rather than winter-spring. The winter results for environmental and child (and home) covariates, with child sick days as the outcome, are shown in Table 27 and 28. These results were only used to guide selection of covariates for use in the GLMM.

The tables show that, of the childcare centre environment covariates, only space per child and temperature showed statistical significance, with the exception of the minimum group size. The surprising result was that the univariate analysis strongly suggested that less space per child was protective against illness. This result not only presented a problem for suggestion of a viable mechanism other than effects on the measurement method, but was contrary to the findings of four out of five studies described in the literature review that had investigated space per child and illness rates. The one remaining study showed no significant association between space and illness rates (see Section 3.3.1).

Temperature showed a consistent pattern of reduced illnesses with higher temperature for every measure except maximum temperature and time under 14^{o}C. Time under 14^{o}C showed a large effect size for risk, but the result was not statistically significant, probably as a result of sample size in that temperature range. Relative humidity and absolute humidity levels did not show a statistically significant result.

Of the child and home covariates, age at the start of the study, attendance at ECE before two years old, NZ European or Chinese ethnicity, more bedrooms in the house, and better health before the study were protective, while Māori or Pacific ethnicity, a higher person to bedroom ratio, having a person in the house with a Community Services Card, and most measures of increased cold, damp or mould were a risk. Of the cold and damp related covariates, the strongest effect was for the presence of mould.

Table 27: Univariate regression for winter sick days per child as an outcome – centre environment

Predictor	Significance	Risk Ratio (RR)	RR Lower (95% CI)	RR Upper (95% CI)	Effect (risk = more illness, protective = fewer illnesses).
Handwashing score	0.562				
Cleaning score	0.227				
Sick child management score	0.670				
Children in the environment (group size) - minimum	0.046	0.755	0.572	0.995	More children is protective, but only at the minimum occupancy level
Children in the environment (group size) - 25th percentile	0.196				
Children in the environment (group size) - median	0.210				
Children in the environment (group size) - 75th percentile	0.159				variables
Children in the environment (group size) - maximum	0.155				
m^2 per child - minimum	0.011	197.947	3.411	11487.3	More space per child is a risk, but upper and lower RR values are widely spaced
m^2 per child - 25th percentile	0.013	63.752	2.392	1697.650	
m^2 per child - median	0.029	35.695	1.451	877.432	
m^2 per child - 75th percentile	0.030	21.911	1.359	353.188	
m^2 per child - maximum	0.009	5.641	1.547	20.573	
m^2 per child - less than 2.0	0.038	0.000	0.000	0.103	More space per child is a risk
m^2 per child - less than 2.5	0.038	0.658	0.444	0.978	
m^2 per child - less than 3.0	0.014	0.914	0.851	0.982	
m^2 per child - less than 3.5	0.061				
Predictor	Significance	Risk Ratio (RR)	RR Lower (95% CI)	RR Upper (95% CI)	Effect (risk = more illness, protective = fewer illnesses).
Temperature - minimum	0.008	0.293	0.118	0.730	Increased temperature is protective
Temperature - 25th percentile	0.014	0.105	0.017	0.634	
Temperature - median	0.004	0.065	0.010	0.416	
Temperature - 75th percentile	0.004	0.066	0.010	0.420	
Temperature - maximum	0.932				
Temperature temp % time under 14°C	0.159				
Temperature temp % time under 16°C	0.015	1.206	1.038	1.401	A greater percentage of time in these temperature ranges is a risk
Temperature temp % time under 18°C	0.000	1.133	1.059	1.214	
Temperature temp % time 14°C to 16°C	0.006	1.324	1.083	1.619	
Temperature temp % time 16°C to 18°C	0.000	1.305	1.163	1.464	
Relative humidity - minimum	0.831				
Relative humidity - 25th percentile	0.566				
Relative humidity - median	0.521				
Relative humidity - 75th percentile	0.529				
Relative humidity - maximum	0.169				
Relative humidity % time under 50%	0.159				
Relative humidity % time 50% to 60%	0.752				
Relative humidity 60% to 70%	0.070				
Relative humidity over 70%	0.808				
Absolute humidity - minimum	0.406				
Absolute humidity - 25th percentile	0.123				
Absolute humidity - median	0.077				
Absolute humidity - 75th percentile	0.062				
Absolute humidity - maximum	0.292				
Absolute humidity % time under 8g/m^3	0.554				
Absolute humidity % time under 10g/m3	0.184				
Absolute humidity % time under 12g/m3	0.144				

Table 28: Poisson univariate regression for winter child sick days as an outcome – child variables and home environment variables, with childcare centre as a random effect

Predictor	Significance	Risk Ratio (RR)	RR Lower (95% CI)	RR Upper (95% CI)	Effect (risk =more illness, protective = fewer illnesses).
Gender	0.045	1.005	1.002	1.197	Being male is a risk, but the effect size is small
Hours of attendance at childcare per week (at time of enrolment in the ECEE study)	0.001	0.993	0.988	0.997	Longer hours of attendance are protective, but the effect size is small
Age in years at start of ECEE study (12/6/17)	0.000	0.879	0.824	0.938	Being older is protective
ECE attendance before 2 years of age	0.000	0.826	0.743	0.919	Attendance at ECE before 2 years old is protective when a child is over 2 years old
Ethnicity Māori or Pacific	0.000	1.362	1.233	1.504	Māori or Pacific ethnicity is a risk, NZ European is protective, while Chinese, Indian or 'other' ethnicities show protective effects but the results are not statistically significant
Ethnicity New Zealand European	0.008	0.638	0.574	0.710	
Ethnicity Māori	0.001	1.195	1.074	1.330	
Ethnicity Samoan	0.000	1.690	1.390	2.055	
Etnicity Cook Island Māori	0.000	1.495	1.187	1.883	
Ethnicity Tongan	0.000	4.881	3.607	6.606	
Ethnicity Niuean	No children of Niuean ethnicity enrolled				
Ethnicity Chinese	0.795	1.030	0.825	1.286	
Ethnicity Indian	0.740	0.966	0.787	1.185	
Ethnicity other	0.087	0.890	0.778	1.017	

Table 28 (continued): Poisson univariate regression for winter child sick days as an outcome – child variables and home environment variables, with childcare centre as a random effect

Predictor	Significance	Risk Ratio (RR)	RR Lower (95% CI)	RR Upper (95% CI)	Effect (risk =more illness, protective = fewer illnesses).
Health status at start of study (parent assessment on Likert scale)	0.000	0.817	0.779	0.861	Better previous health is protective
Other children in household attending ECE (count)	0.022	0.905	0.831	0.986	Other children in the house attending ECE is protective
Other children in household attending school (count)	0.087	0.950	0.897	1.007	Having other children in the house attending school did not show a significant result
Household number of occupants	0.105	0.961	0.916	1.008	The number of occupants in the house was not statistically significant for illness
Household number of bedrooms	0.000	0.850	0.806	0.897	More bedrooms are protective, while a higher person to bedroom ratio is small but significant a risk
Household person to bedroom ratio	0.003	0.864	0.815	0.915	
Smoking inside the house	Only one house had a person who smoked inside				
House too cold (parent assessment on Likert scale)	0.740	0.991	0.939	1.046	A house feeling too cold was not statistically significant for illness
House smells damp (parent assessment on Likert scale)	0.000	1.262	1.180	1.349	A damp-smelling house, mould in the house, being able to see your breath in the house or shivering in the house are risks
Mould in house (parent assessment on Likert scale)	0.000	1.248	1.182	1.317	
Can see breath inside house (parent assessment on Likert scale)	0.035	1.085	1.006	1.171	
Sometimes shiver in the house (parent assessment on Likert scale)	0.003	1.127	1.043	1.218	
Income	0.0849	1.015	0.998	1.032	Income is not statistically significant for illness, but having a Community Services Card holder in the household is a risk
Community Services Card holder in household	0.000	1.598	1.446	1.768	

6.5.2 Space per child and illness rates – generalised linear mixed modelling (GLMM)

Inclusion of hypothesis predictor variables

Of the four predictor variables in the hypotheses (crowding, temperature, RH and AH), only crowding and temperature showed significant association with sick days in univariate analysis. RH was nowhere near significance in univariate analysis, and while AH approached significance at 0.06, it would have needed to have been included with much more significant variables in the multivariate model. Multivariate modelling for AH with temperature, and space per child, reduced the significance of AH, so this analysis was not taken further.

Prioritising centre and child variables

Using the univariate Poisson regression results to guide choice of covariates, space per child was initially analysed in the GLMM modelling with two measures of m^2 per child (minimum and median), and the following child variables as controls:

- Age in years at start of study
- ECE attendance before two years old
- Māori or Pacific ethnicity
- Person to bedroom ratio
- Damp smell in the house
- Mould in the house
- Community Services Card use

The results were sorted by Akaike's Information Criterion number (AIC) for best fit. Minimum space per child showed consistently better fit than median, and from the child variables the following were chosen in order of best fit:

1. Mould in the house
2. Māori or Pacific ethnicity
3. Community Services Card use
4. Age at start of study
5. ECE attendance before two years of age

Hierarchical inclusion of covariates for best-fit model

The five prioritised child variables, and the centre variable median temperature, were then used in Poisson GLMM modelling to identify the correlation between space per child and child sick days, as follows:

glmer (child sick days~ minimum m^2 per child + median temperature +

child covariate (1) +

child covariate (2) +

child covariate (3) +

child covariate (4) +

child covariate (5) +

(1| Environment ID number),

family="poisson", data= (source data filename)

GLMM results

Table 29: GLMM results for child sick days and minimum m^2 per child

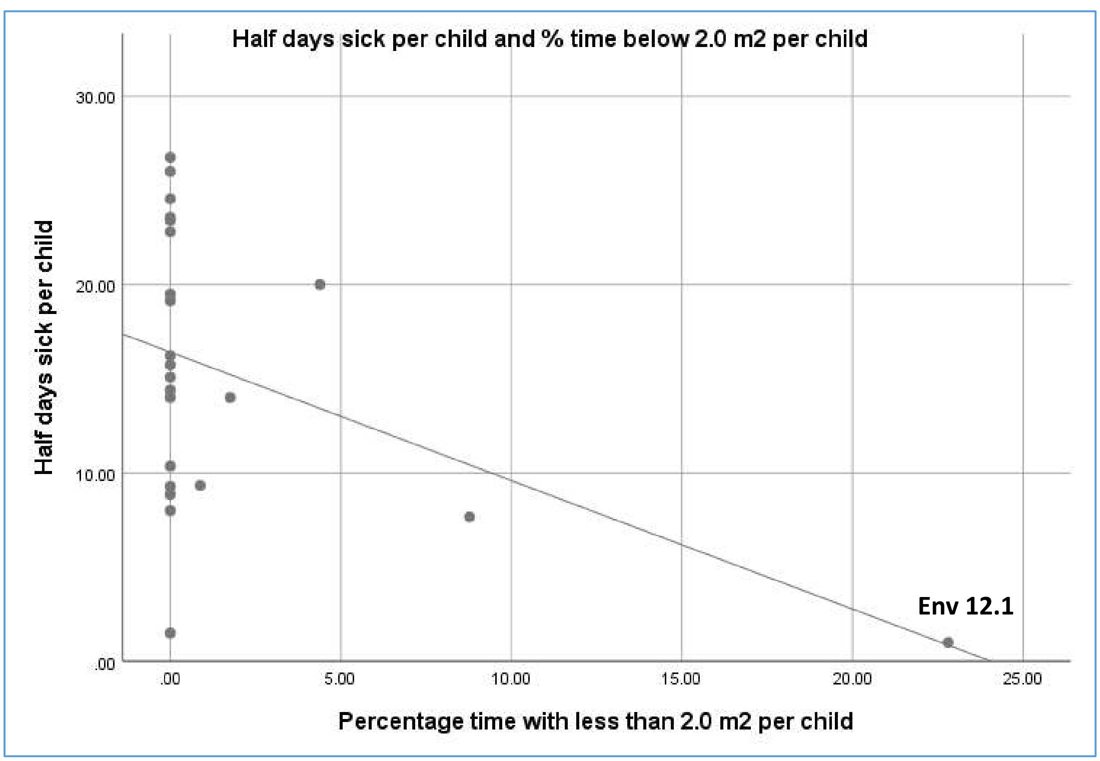
Winter-Spring	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Minimum m^2 per child	2.132	1.328	1.222	3.720	2.666	0.008
Median temperature	0.840	1.144	0.646	1.092	-1.301	0.193
Mould in house score	1.063	1.030	1.002	1.127	2.032	0.042
Māori or Pacific ethnicity	1.455	1.042	1.343	1.577	9.173	< 2e-16
Community Services Card	1.171	1.051	1.062	1.291	3.176	0.001
Age at start of study	0.770	1.027	0.731	0.811	-9.931	< 2e-16
Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Minimum m^2 per child	1.711	1.294	1.032	2.835	2.084	0.037
Median winter temperature	0.770	1.127	0.609	0.974	-2.182	0.029
Mould in house score	1.179	1.029	1.114	1.248	5.697	0.000
Māori or Pacific ethnicity	1.260	1.054	1.137	1.395	4.424	0.000
Community Services Card	1.220	1.061	1.087	1.370	3.365	0.001
Age at start of study	0.873	1.033	0.819	0.930	-4.21	0.000

The best-fit models are shown in Table 29. The model would not converge when ECE attendance before two years was included. The initial results indicated that, after controlling for median temperature and the child covariates shown, sick days could be expected to increase 2.1 times for each increase of 1m^2 activity space per child (95% CI 1.2–3.7) during winter-spring and 1.7 (95% CI 1.0–2.8) times for winter.

Results after removal of an outlier (point of high leverage)

The measurements of m^2 per child described in Section 6.4.1 showed one centre with very low allocation of space per child (Environment 12.1), and this centre also had unusually low sick days per child. A scatter plot of sick half days per child (see Figure 52) showed this centre to be an outlier for these two values – a point of high leverage in the data. Childcare centre number 12 (Environments 12 and 12.1) was one of only two centres that had age-group division in the two to five year age range. Environment 12.1 was only for children aged three to five years, and 100% of children in this environment had attended before two years of age.

Figure 52: Half days sick per child (enrolled in the ECEE study) and percentage time at less than 2.0m^2 per child



The GLMM modelling was also run with the exclusion of Environment 12.1 (eight children). The model would not converge when Community Services Card use or attendance at ECE before two years were included in the model. For the winter-spring period, exclusion of Environment 12.1 showed a reduction in effect size and significance (RR 1.7, 95% CI 1.0–2.8), but for winter the result became insignificant, with 95% confidence limits either side of 1 (Table 30).

Table 30: GLMM results for child sick days and minimum m^2 per child, excluding Environment 12.1

Winter-Spring excl. 12.1	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Minimum m^2 per child	1.700	1.288	1.035	2.790	2.098	0.036
Median temperature	0.875	1.121	0.700	1.095	-1.168	0.243
Mould in house score	1.089	1.029	1.029	1.153	2.962	0.003
Māori or Pacific ethnicity	1.466	1.042	1.353	1.588	9.339	< 2e-16
Age at start of study	0.780	1.026	0.741	0.821	-9.516	< 2e-16
Winter excl. 12.1	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Minimum m^2 per child	1.465	1.280	0.904	2.376	1.549	0.121
Median winter temperature	0.791	1.116	0.638	0.981	-2.133	0.033
Mould in house score	1.229	1.035	1.150	1.314	6.049	0.000
Māori or Pacific ethnicity	1.326	1.053	1.199	1.466	5.511	0.000
Age at start of study	0.885	1.033	0.831	0.943	-3.786	0.000

6.5.3 Multicollinearity

A correlation table was generated to check for potential collinearity between predictor variables. The correlation table had 134 predictor variables, due to the splitting of environmental variables by season, percentile and threshold, and for that reason is not reproduced in full. The correlation table indicated potential collinearity between space per child and the other predictors in the model, with the exception of Māori or Pacific ethnicity (See Table 31).

Table 31: Correlations between predictor variables

	M^2 per child minimum	Winter temp median	Mould in house score	Māori or Pacific ethnicity	Community Services Card	Age at start of study
Winter temperature median	-0.299					
Mould in house score	0.162	-0.050				
Māori or Pacific ethnicity	0.079	-0.007	0.189			
Community Services Card	0.255	-0.043	0.140	0.084		
Age at start of study	0.103	0.098	0.073	-0.001	0.026	
ECE attendance before 2 years	-0.352	0.113	-0.119	-0.038	-0.237	-0.166

A check was also made for changes in the standard error of the intercept as predictor variables were added to the model. The result indicated a large change in the exponentiated univariate standard error of the intercept, from 2.020 for the univariate model, to 11.001 when median temperature was included in the model (see Appendix 15). Very little change was seen in the intercept standard error when the other variables were combined with 'm^2 per child' in the model.

6.5.4 Temperature and illness rates

Considering the unexpected result for space per child and child sick days, indications of collinearity between temperature and space per child, and the effect on the standard error described in Section 6.5.3, the GLMM modelling for temperature as a predictor of child sick days was calculated without the predictor ‘m^2 per child’. The correlation table (Table 31) also indicated potential collinearity between the predictors ‘Age at start of study’ and ‘ECE attendance before 2 years’, with ‘ECE attendance before 2 years’ also showing collinearity with other variables, except ethnicity. In some instances the models would converge when either one, but not both of these variable were included. For these reasons ‘ECE attendance before 2 years’ was not included in the final models.

GLMM modelling for the relationship between temperature and illness rates indicated that risk of illness reduced with increasing temperature for the 25th percentile, median and 75th percentile temperatures (Table 32).

Table 32: GLMM results for winter child sick days and temperature by quartile

Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR))	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
25th percentile temperature	0.747	1.128	0.591	0.946	-2.421	0.015
Mould in house score	1.180	1.029	1.115	1.249	5.707	0.000
Māori or Pacific ethnicity	1.264	1.054	1.141	1.401	4.495	0.000
Community Services Card	1.225	1.061	1.091	1.376	3.434	0.001
Age at start of study	0.874	1.033	0.820	0.931	-4.164	0.000
Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Median temperature	0.721	1.135	0.563	0.924	-2.589	0.010
Mould in house score	1.180	1.029	1.115	1.249	5.728	0.000
Māori or Pacific ethnicity	1.263	1.054	1.140	1.399	4.468	0.000
Community Services Card	1.225	1.061	1.091	1.375	3.426	0.001
Age at start of study	0.875	1.033	0.821	0.933	-4.116	0.000

Table 32 (continued): GLMM results for winter child sick days and temperature by quartile

Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
75th percentile temperature	0.736	1.135	0.574	0.943	-2.419	0.016
Mould in house score	1.181	1.029	1.116	1.250	5.739	0.000
Māori or Pacific ethnicity	1.262	1.054	1.139	1.398	4.458	0.000
Community Services Card	1.224	1.061	1.090	1.374	3.416	0.001
Age at start of study	0.875	1.033	0.822	0.933	-4.108	0.000

The results indicated a decrease in sick days of 25% to 28% for one degree increase in temperature. The GLMM model for median temperature generated the warning in R:

"Model failed to converge with max|grad| = 0.00109254 (tol = 0.001, component 1)",

but the result was very close to tolerance. When the variable 'Age at start of study' was removed, the result was similar and the model converged, showing a decrease in sick days of 29% for each degree increase in median temperature (see Table 33), compared with 28% in the model in Table 32. The model had an increased AIC value (indicating poorer fit).

Table 33: GLMM results for winter child sick days and median temperature, excluding 'Age at start of study'.

Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Median temperature	0.713	1.134	0.557	0.913	-2.681	0.007
Mould in house score	1.188	1.029	1.122	1.257	5.931	0.000
Māori or Pacific ethnicity	1.255	1.053	1.134	1.390	4.38	0.000
Community Services Card	1.196	1.061	1.066	1.342	3.039	0.002

GLMM modelling by temperature threshold did not produce a significant result for time spent under 14ºC, but there were statistically significant effects for percentage of time under 16ºC and under 18ºC (see Table 34). The results indicated a 2.5% increase in sick days for each percentage point of time spent under 16ºC (95% CI 0.6–4.6%), and a 1.5% increase in sick days for each percentage point of time spent under 18ºC (95% CI 0.3–2.4%).

Table 34: GLMM results for winter child sick days and temperature by temperature threshold, including space per child

Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Percentage time under 14ºC	1.053	1.031	0.992	1.118	1.69	0.091
Mould in house score	1.181	1.029	1.116	1.250	5.746	0.000
Māori or Pacific ethnicity	1.264	1.054	1.141	1.400	4.487	0.000
Community Services Card	1.222	1.061	1.088	1.372	3.386	0.001
Age at start of study	0.873	1.033	0.820	0.931	-4.18	0.000
Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Percentage time under 16ºC	1.025	1.010	1.006	1.046	2.52	0.012
Mould in house score	1.180	1.029	1.115	1.249	5.709	0.000
Māori or Pacific ethnicity	1.265	1.054	1.142	1.401	4.502	0.000
Community Services Card	1.225	1.061	1.091	1.375	3.428	0.001
Age at start of study	0.873	1.033	0.820	0.931	-4.178	0.000
Winter	Fixed effects					
Outcome = child sick half days	Rate ratio (RR)	EXP Std. Error	RR 95% LL	RR 95% UL	z value	Pr(>|z|)
Percentage time under 18ºC	1.015	1.005	1.006	1.024	3.207	0.001
Mould in house score	1.180	1.029	1.115	1.249	5.715	0.000
Māori or Pacific ethnicity	1.263	1.054	1.140	1.399	4.471	0.000
Community Services Card	1.225	1.061	1.091	1.375	3.427	0.001
Age at start of study	0.874	1.033	0.821	0.932	-4.147	0.000

While there was a significant effect for time spent under 18°C, this effect could be generated by the time spent under 16°C or lower, especially as the under 18°C effect was less than the under 16°C effect. Additional information was required to determine whether the time at temperatures between 16°C and 18°C was contributing to inverse relationship between temperature and illness.

Table 35: Temperature ranges for temperature quartiles in relation to sick days

Outcome = child sick half days	Risk ratio (RR) from Table 32	Childcare centre temperature range (°C)		
		Min	Mean	Max
25th percentile temperature	0.793	15.2	16.9	18.9
Median temperature	0.770	16.5	18.0	19.9
75th percentile temperature	0.787	17.3	18.9	20.8

The temperatures that matched to the 1st, 2nd and 3rd quartiles are shown in Table 35. The median temperature range was 16.5°C to 19.9°C (mean 18.0°C), while for the 75th percentile the range was 17.3°C to 20.8°C (mean 18.9°C). This indicates that the significant inverse relationship between temperatures and illness rates applied in the upper-teen temperature ranges, at least above 17.3°C.

6.5.5 Analysis by symptom group

GLMM analysis for symptom groups was attempted, but even for the largest symptom group, total respiratory infections, the results were not statistically significant. Separate analysis for the outcomes of child absence from childcare (due to illness), and parent days off work (due to child illness), were not performed as the outcomes were directly consequential to child sick days, but with reduced incidence. The value in recording absences was to describe an impact of the illnesses.

6.6 Summary

6.6.1 Study methods and participation

The final data set was for 221 children, which did not allow for analysis of illness groups. The number of childcare centres involved in the whole study (21 centres with 23 environments) was larger than for other comparable studies, however (see Section 3.4). Of the childcare centres contacted for the study, 18 declined involvement, 6 did not reply (either initially or after first contact), and 13 were ineligible. Of the parents of children who filled out the enrolment forms for their children, 85% completed the website training and background questionnaires. Of those who completed the initial process, 97% completed all records for their children's illness.

The website data required very few corrections and follow-up phone calls at the end of the study. The time required to keep the information flowing from both the centre managers and the parents was substantial – close to a full-time role for five months. The Wireless Tag system had reliability problems, mainly related to power outage or plug disconnection and failure of remote alert systems (e.g. lost signal).

6.6.2 Sample populations

The childcare centre group size ranged from 22 to 50, with all centres except one open at 7:00 a.m. to 7:30 a.m. and closing at 5:30 p.m. to 6:00 p.m. One centre was open 8:00 a.m. to 4:30 p.m. The ethnic distribution of the centres was similar to that expected for childcare centres in the study geographic area, based on Census data. The predominant form of heating was heat pumps, with four using flued gas radiators, two using gas underfloor heating, and one using infrared heating. Most activity spaces had doors to the outside open on most days. Three of the environments had mechanical ventilation for their activity areas, while the remainder relied on doors or windows. The types of building were diverse, including seven 'purpose-built' centres, eight converted houses, and seven converted industrial buildings. There was a lot a variation in hygiene practices, including poor practice in relation to handwashing after nappy change or nose-blowing.

The age range of children at the start of the study was 1.96 years to 4.93 years, with 119 girls and 102 boys. Two of the centres had separate areas for children within the study age-group: one with the division at three years, and the other at three years nine months. Attendance hours of children enrolled in the study ranged from 6.75 hours per week up to 55 hours per week, with a median of 32.50 hours. Most children (91.4%) attended for 18–23 weeks of the study. 78% of parents described their children's general health at the start of the study as very good or excellent, with 6% describing their child's health as 'fair' or 'poor'.

75% of homes had two to four occupants, while the remainder had five to seven occupants. 91% of homes had one to two people per bedroom, while 6% had more than one bedroom per person. There was evidence of coldness and damp in homes: about half of the respondents (49%) indicated that their homes were too cold during winter; 20% reported their house smelling damp or musty at times; and 29% reported mould in living areas, bedrooms or the kitchen. Only one household had a person who smoked in the house.

6.6.3 Child illness outcomes, time away from childcare and parent lost work time

The study recorded a total of 390 illness events, resulting in 1,715.5 sick days over 23 weeks. Total respiratory illnesses were the most frequent, accounting for 68% of illness events. Febrile illnesses accounted for 47% of events, while enteric illnesses accounted for 27%. A chickenpox outbreak during the study affected several centres, accounting for 5% of illness events. Compared with the spring season, the winter season generated 33% more child sick days per week, 38% more days lost from childcare per week, and 22% more parent lost-work days and total illness events per week.

On average, children were sick one day every 2.7 weeks, with one day absent from childcare (a day they would normally attend) once every five weeks. For parents who reported that they lost work time, the average loss was one day per 4.8 weeks (about 5.5 days per winter-spring half-year), with a median of one day per 5.9 weeks (about 4.5 days per winter-spring half-year).

There was a very wide range of mean days of illness per child across the childcare centres, from 0.5 to 13.4 days during the study period.

6.6.4 Childcare centre conditions and compliance with regulations

The study found that 90% of centres were breaching the minimum temperature regulations for ECE environments in winter, with 67% operating below 16°C for between 10% and 36% of the time, and one centre below 16°C for 60% of the time. Some centres were operating below 14°C in winter, in one case for more than a quarter of the time. Median winter temperatures ranged from 16.5°C to 19.9°C, with a mean of 18.0°C.

Across the centres, space per child varied considerably, with median space per child ranging from 2.23 to 4.35m^2 per child. The study found that 10 out of 23 environments (9 out of 21 centres) were breaching the minimum regulations for space per child (2.5m^2) at least 10% of the time, and up to a maximum of 86% of the time. Four centre environments (from three centres) were operating at times below 2.0m^2 per child. The study found that three environments (from two childcare centres) had been incorrectly licensed by the Ministry of Education, with a licence for a larger number of children than the space could legally accommodate.

Relative humidity data showed little overall variation across the winter-spring seasons. Winter median relative humidity was in the range 53% to 71%, while the spring equivalent values were a little drier at 47% to 68%. There were some high humidity levels, however, in excess of 85%.

CO_2 monitoring in sleep rooms indicated poor ventilation, with steep rises and falls in CO_2 as the rooms were occupied and the doors closed. Six sleep rooms had levels exceeding 3,000ppm, with the highest level being 3,792ppm. Another two exceeded 2,000ppm. Only one had levels consistently below 1,000ppm.

6.6.5 Correlation of illness rates with environmental conditions

Univariate linear regression indicated that, of the childcare centres' environmental conditions, only increased space per child (risk) and increased temperature (protective) were significantly correlated with illness rates, while there was little or no correlation between group size or relative humidity and illness rates. Of the child and home covariates, age at the start of the study, attendance at ECE before two years old, NZ European or Chinese ethnicity, and better health before the study were protective, while Māori or Pacific ethnicity, more people in the house or higher person to bedroom ratio, having a person in the house with a Community Services Card, and most measures of increased cold, damp or mould were a risk.

GLMM indicated that increased space per child may be a risk for illness rates, while increased temperature was protective against illness. The effect remained after controlling for temperature, child age, ethnicity, mould in the home, Community Services Card use. This was an unexpected result. The space per child result was however affected multicollinearity (each instance of collinearity weighting the result towards increased space as a risk), and by a point of high leverage, (one centre with very low space per child and very low illness rates). For the winter-spring period, exclusion of the outlier from the data showed a reduction in effect size and significance for winter-spring (RR 1.7, 95% CI 1.0–2.8), while for winter the result became insignificant, with 95% confidence limits either side of 1.

GLMM for the relationship between temperature and illness rates indicated that risk of illness reduced with increasing temperature for the 25th percentile, median and 75th percentile temperatures. The results indicated a decrease in sick days of 25% to 28% for every degree increase in temperature. The results also indicated a 2.5% increase in sick days for every percentage point of time spent under 16^{o}C (95% CI 0.6–4.6%), and a 1.5% increase in sick days for every percentage point of time spent under 18^{o}C (95% CI 0.6–2.4%). With median temperatures ranging from 16.5^{o}C to 19.9^{o}C (mean 18.0^{o}C), and the 75th percentile temperatures in the range from 17.3^{o}C to 20.8^{o}C (mean 18.9 ^{o}C), the significant inverse relationship between temperatures and illness rates applies in the upper-teen temperature ranges, at least above 17.3^{o}C.

GLM analysis for symptom groups was not statistically significant, and it is likely that the sample size was insufficient for this level of analysis.

7 Discussion and conclusions

From the introductory chapter, the aims of this thesis were to:

1. Explore the literature related to environmental conditions in ECE centres, and to infections related to ECE and care attendance.
2. Measure occupancy rates, temperatures and humidity in ECE centres.
3. Measure illness rates for children in ECE centres, and absences due to illness.
4. Measure parental absences from work due to their child's illness.
5. Identify relationships between the environmental conditions, and illness and absence rates.

Key findings

The key findings of the study were as follows:

1. The sample environments showed poor compliance with Ministry of Education requirements for space per child (less than 57% of environments complied), and temperature (less than 9% of environments complied).
2. Increased temperatures in the range 15.2ºC to 20.8ºC were associated with reduced child sick days.
3. More space per child was associated with increased child sick days, but this result may be due to problems with the proxy measurement, and multicollinearity.
4. No significant association was found between and child sick days and either RH or AH.
5. For parents needing to take time of work because of their child's illness, the average six month (winter-spring) time demand exceeded New Zealand's minimum annual sick leave allowance of 5 days.
6. Mould and dampness in homes were significant predictors of increased child sick days.

This chapter discusses the empirical results of the ECEE study, study limitations, and conclusions regarding the key findings. It also considers the research method for illness data collection, as this method had not been previously attempted in New Zealand in the ECE sector.

The chapter discusses some of the findings that were not central to the hypothesis, but which are useful for engagement with the ECE sector or for associated areas of research. This chapter also discusses some relevant policy developments that have taken place while the study was being conducted.

7.1 Environmental conditions

The measurement of operating conditions in a representative group of full-day childcare centres had not been done previously in New Zealand, but a Ministry of Education spokesperson had claimed “98% compliance with regulations” [219].

The study results revealed a much higher level of non-compliance than expected. They showed very cold conditions in some centres, a wide range of space per child with some very crowded spaces, as well as some very high CO_2 levels. Where a centre had very low temperatures or non-compliant space per child, the centre’s results were discussed with the centre manager. The overall results were also discussed with the Ministry of Education (Lower Hutt office), while not disclosing the identity of centres from which the results were obtained. The Ministry of Education could not offer a reason for the most serious licensing errors, and agreed that the corridor spaces should not have been included in licence calculations. Many of the less serious breaches were not due to licensing error, however.
The reason for the low temperatures (below 16°C, or lower than user-stated target temperatures) may have more to do with the ability of the heating systems to cope with heat loss through open doors, rather than an intention to operate at cold temperatures. Cooler winter mornings on dry days would have presented the challenge of achieving a 10-15°C increase over outdoor temperature while having outside doors opened often. In Phase One of the study, centre managers were asked, “Is there a minimum temperature you aim for in this activity space? If yes, what is the minimum temperature you aim for?” There was no relationship between the measured temperatures and the expressed target temperatures, with

the coldest centre aiming for 18–20ºC, while its median winter temperature was only 15.3ºC. Of the thirteen centres with median temperatures below 18ºC, six were aiming for 18ºC as a minimum. Manager comments included, "Not optimal arrangement of different heat pump locations and sizes"; "Struggles to reach temperature if the door is open"; "Poor performance on cold days"; "Affected by open door"; and "[Heat pump] set to 22ºC or 24ºC to try to reach minimum temperature."

The need for outside doors to be open was given by the Ministry of Education as a reason for the 16ºC minimum temperature [77].

The results in the ECEE study are similar to the results reported by Passauer and Wirsing [191], in which 27% of their minimum temperature measurements were below 16ºC at 0.5m above the floor (see Section 3.4.9). In the ECEE study 67% were operating below 16ºC for between 10% and 36% of the time.

The centre cohort did not provide a sufficient sample of heating types to draw conclusions about the comparative effectiveness or efficiency of the different systems. Only one centre used infrared heating, and that centre was mid-range in the winter temperature profiles (10% of time under 16ºC, median 17.8ºC), while using 16ºC as the minimum target temperature. Only one used underfloor heating and that centre had the warmest profile, but the manager did not have control of the system and did not know the target temperature. The physics of heat distribution would suggest two mechanisms that may need to be considered in heating design for ECE environments:

1 Vertical heat distribution

Given the tendency for warm air to rise, a high-mounted heat pump may have difficulty in achieving even heat distribution between upper and lower levels in a room. This may be giving rise to a perception of warmth by teachers while child-level temperatures are too cold. Both underfloor heating and infrared heating may address this problem, one by warming a room from the bottom up, and the other by having heat absorbed by solid surfaces (including floors, tables and children's bodies) (see Section 2.5.2).

2 Thermal mass and ventilative heat loss

The open doors of many centres allow loss of warm air. This is particularly a problem when heat pumps are located close to outside doors. Infrared systems may be preferable, as they directly heat the thermal mass of the building, which may reduce heat loss when doors are opened (see Section 2.5.2). Another option that may be worth considering is the use of air curtain technology often used in shop entrances. Air curtains are specifically designed to separate thermal zones, in situations where doors need to be kept open.

The high CO_2 levels in sleep rooms and in the one activity space that was monitored, may result from a lack of awareness of the need for ventilation, and a lack of attention to design for ventilation both by the Ministry of Education and Public Health Units. None of the rooms sampled had passive ventilation other than an openable window, except for one that was open to a stairwell and had a gap to an adjacent indoor space at ceiling level.

7.2 Illnesses and absences

The illness rates on their own are not causally attributable to childcare attendance, but they give an indication of impact on the sick leave resources of working parents. For parents who reported that they lost work time, the average loss was one day per 4.8 weeks (about 5.5 days per winter-spring half-year), with a median of one day per 5.9 weeks (about 4.5 days per winter-spring half year). The minimum sick leave provision in New Zealand is five days a year (Holidays Act 2003).

The ECEE study results for sick leave only reveal the demands on parents from the care of one child as a result of an infection. They do not take into account sibling or parent illnesses, injuries or any other sick leave needs. Inadequate sick leave places pressure on teachers and parents to work while they are sick. In 2017 research by Susan Bates, 43% of ECE teachers survey (n = 707) reported working while sick [76].

A question about sick leave provision, posted on the Teachers Advocacy Group Facebook page (2,043 members) on 23 November 2018, confirmed that this was the case for some teachers [220]. Some respondents reported much better than five days sick leave per year (up to 12, cumulative to 62), and caring employers, but one response was, “We get five [days sick leave per year] and I work for a corporate which can be challenging for our teachers with children." Another reported, "All places in Auckland I've worked [get] 5 days and we work with children." Another respondent, referring to sick leave from a very big corporate childcare provider, said sick leave provision was, "Five days (after 3 months), plus additional days, with the caveat that if [the employer] thought these days were being 'abused' they would be revoked. So basically, if you used them you lost them, but they got to market 'generous leave'."

Low sick leave provision also places pressure on parents to take sick children to childcare, and on teachers to accept them [11]. Working while sick, or attending childcare while sick, is likely to increase the risk of infection spread, and in the case of teachers reduce their quality of work.

Cost of illness

The mean number of periods of illness and the mean number of days sick per child per year in the ECEE study were overall very similar to those found in the Helsinki study in 1985-86 [192], that estimated costs of illness due to illness in childcare. For the Helsinki study these figures were 4.9 illness episodes and 22.9 sick days per child per year, while the equivalent rates in the ECEE study were 5.1 illness episodes and 22.9 sick days. The Helsinki data was for children from birth to six years of age however, with data split at age three years. The days sick per child for children under three years was 39.3 days per year, and for children over three years it was 17.0 days sick per year. An expected New Zealand rate for a birth to six year age range would be higher than 22.9 days per year, as the ECEE study excluded children under two years old. The Helsinki study estimated illness related costs at US$3,525 for children under the age of three years and $1,012 for older children annually, for a total of US$22,485,000 in 1990 terms, for a population of 871,274 [221]. The estimate took into account childcare days lost (but paid for), medical costs, paid nursing costs and parental lost work time. From this data an expected New Zealand equivalent cost would be in excess of US$200 million per year in today's terms, or in the order of NZ$300 million. In New Zealand it would be unusual to have paid nursing costs, so this aspect of the costing would need to be deducted by the allocated nursing cost proportion in the Helsinki estimate of 6%.

7.3 Illnesses and indoor space per child

The space per child results were unexpected. The correlation table indicated that three of variables in the model (median temperature, mould in house score, and age at start of study), could have affected the accuracy of the result.

While temperature was negatively associated with space per child, there was very little association between temperature and the size of the space, ($R^2 = 0.014$). It is possible that crowding could increase room temperature, so it is possible that these variables could be confounded. It was difficult to imaging genuine confounding for the other correlated variables in the model however, so they may be result of sample size.

While the results need to be considered as a possible representation of a real effect, neither I nor my colleagues could propose a mechanism that could explain a direct protective effect against illness from increased crowding, other than the possibility of crowding affecting room temperature. The only explanations we could suggest relied on the effect of extraneous variables, such as the attractiveness of the outdoor space, variables already controlled for such as child age, or variables found to have no significant effect, such as group size. Four of the five studies found in the literature review that addressed space per child, reported evidence for reduced illness with reduced crowding, and there were no indications in the literature review of an opposite effect. The centres in the study by Alexandrino et al [145], which showed decreased space per child as a significant risk, were very similar in space per child allocation to the centres in the ECEE cohort, but with fewer children per room (9–12), a younger age-group (up to three years old), and only six childcare centres for environmental comparison.

The removal of the environment described as an outlier had the effect of rendering the winter result statistically insignificant, while for the whole study period the effect was reduced, but remained significant. The centre provided spaces for children under two years (separate environment), so it is likely that many or all of these children had been at that particular childcare centre since they were less than two years old, with potential for increased immunity. The centre also had a large indoor space area that had formerly been a truck garage, with large doors opening to the outdoor area. It was categorised by the Ministry of Education as outdoor space, but this space made it possible to have fewer children in the activity space licensed as ‘indoors’.

Aside from the effect of the outlier, the most likely explanations for this result are:

1. The measure of crowding. The use of Ministry of Education attendance data provides a daily count of children on site, and an accurate measure of legal compliance. When combined with indoor floor area, it can only provide an indicator of maximum indoor crowding on any given day, which is not necessarily the predominant level of crowding.

2. Confounding, in relation to temperature, and multicollinearity in relation to other predictor variables, other than Māori or Pacific ethnicity.

3. Small sample size, resulting greater effect of random correlations in the sample.

4. Possible inaccuracies in illness counts due to sick child attendance.

5. A possible feedback mechanism in which crowded conditions encourage children to move outside (related to the first explanation).

7.4 Illnesses and indoor temperatures and humidity

The temperature analysis in the ECEE study showed that the relationship between increased indoor temperatures and reduced illness applied in the upper-teen temperature range, from at least 17.3^{o}C.

There were difficulties with collinearity and potential confounding between temperature and space per child. When space per child was included in the GLMM, the effect size of the negative relationship between child sick days and each degree increase in median temperature, was reduced from 28% down to 23% (see Table 29). It is unlikely however, that the space per child effect was real, given problems with multicollinearity in the GLMM model for space per child, and a lack of plausible mechanism. For these reasons, the result without control for space per child has been taken as the more accurate estimate of the association between child sick days and temperature.

While infectious organisms will include bacteria, protozoa, viruses and fungi, it is likely that viruses are the group of infectious agents responsible for most infections in ECE and care environments, and that factors affecting viral, rather than bacterial survival may be the most important. This view is supported by the predominance of short-term respiratory infections in this study (see Section 6.3.1), and the findings in the literature review; a Turkish study found 44.4% of the childhood gastroenteritis cases were viral [128], and a Dutch study that the four most common organisms detected in their surveillance were norovirus, rotavirus, *G. lamblia*, and astrovirus [132].

Following the completion of the literature review, some new information was published that strongly suggested environmental viral survival as a plausible mechanism for the ECEE study result. Prussin et al. [222] reported on a study of viral infectivity under various temperature and humidity conditions, using the bacteriophage Phi6 (an enveloped virus used as a surrogate for influenza viruses, and coronaviruses). The authors stated that, "Contrary to our initial hypothesis that temperatures over the range of that typically found indoors (19 to 25°C) do not have a significant effect on virus infectivity, we found that… over this range, virus infectivity decreases exponentially with increasing temperatures." They found that at a fixed relative humidity (RH) of 75%, infectivity decreased two orders of magnitude between 19°C and 25°C, while Phi6 survived best at high (>85%) and low (<60%) RH, with a significant decrease in infectivity at mid-range RH (60–85%).

This finding is consistent with the reduced illness rates in the median (16.5°C to 19.9°C) and 75th percentile (17.3 to 20.8°C) temperature ranges. The lack of a significant association between either RH or AH with illness rates in the ECEE study may have to do with the humidity range, and with a relationship between humidity and viral infectivity that is more U-shaped than linear [156].

Deyle et al. have stated:

> …we clarify that, absolute humidity drives influenza outbreaks across latitudes, that the effect of absolute humidity on influenza is U-shaped, and show that this U-shaped pattern is mediated by temperature [223].

The AH result was, however, closer to significance than for RH. When considering the seasonality of influenza in temperate climates, Shaman and Kohn have found that 50% of variability in influenza virus transmission, and 90% of variability in the survival of the virus are explained by AH, whereas, 12% and 36% respectively are explained by RH [224]. It may be that given a greater sample size, a significant effect of AH may have been detected. Prussin et al also found a relationship between AH and viral infectivity: “Our results show that at an AH of less than 22 g/m^3, the loss in infectivity was less than two orders of magnitude; however, when the AH was greater than 22 g/m^3, the loss in infectivity was typically greater than six orders of magnitude.” 22g/m^3 represents very high humidity. For comparison, the highest AH recorded in the ECEE study was 16.8g/m^3, so the relationship between viral infectivity and AH may have been more linear in the range measured in the ECEE study. In the ECEE study, the AH across the 23 environments was in the range 8g/m^3 to 12g/m^3 for 60% to 87% of the time. This may mean that there was insufficient variation in AH between environment to allow an effect to be measured a significant level.

Since the literature review for this thesis the World Health Organisation produced the *WHO Housing and Health Guidelines* (2018) and the New Zealand Ministry of Housing and Urban Development released the *Healthy Homes Standards* (2019) [225]. The WHO recommendation in relation to indoor temperature in housing reads:

> Indoor housing temperatures should be high enough to protect residents from the harmful health effects of cold. For countries with temperate or colder climates, 18˚C has been proposed as a safe and well-balanced indoor temperature to protect the health of general populations during cold seasons. [226]

The strength of the recommendation is given as ‘strong’. The *Heathy Homes Standards* require homes to be able to be heated to a minimum 18^{o}C, based on the WHO recommendation. Underpinning the WHO recommendation was a review by Telfar Barnard et al, described in Web Annex B of the *WHO Housing and Health Guidelines* [227]. The finalized research question for the review was:

> Do residents living in housing where indoor temperatures are below 18^{o}C have worse health outcomes than those living in housing with indoor temperatures above 18^{o}C?

The authors gave the certainty of the evidence for an 18°C minimum temperature as 'moderate' in relation to risk for both respiratory mortality and morbidity, and for cardiovascular mortality and morbidity (particular for the elderly). These conclusions relate to studies that focus on the effects of temperature on the body, for example from the University of Otago research that had identified an effect of temperature below 12°C on lung function [160].

It may be however that in ECE and care environments, pathogen environmental survival and transmission are the more important factors in rates of infection, and that this may related to temperatures above those that affect significant body response to temperature. At low indoor temperatures (possibly 12°C or less), body response may become a more significant factor. The ECEE study results support maintaining higher temperatures in the upper teen (°C) range, but the study did not detect a clear threshold of effect within that range. A minimum indoor temperature in ECE and care environments of 18°C rather than 16°C is likely to result in a reduction in illness in both children and teachers if environmental survival is the main mechanism for increased infections. Given that New Zealand ECE and care centres are struggling to achieve the current 16°C minimum, extending the minimum beyond 18°C in the New Zealand may be impractical in the short term. More work is required to identify systems suitable for low-level heating (0.5m to 1.0m above floor level), in buildings with high indoor-outdoor airflow.

7.5 Other variables: Child age, starting age in care, home conditions

The ECEE study indicated that ECE and care attendance before two years of age reduced infection risk for children in the study cohort, but the study did not record starting age after two years. The ECEE study found that being older was protective from two years of age upwards, but could not identify whether later starting age after two years had an effect.

The study indicated that home environment variables could be as important, or more important than ECE centre environment variables, particularly the presence of mould in the living areas, bedrooms or kitchen, or damp smell in the house. In univariate regression, measures of home indoor coldness such as ability to see breath or shivering, and higher person to bedroom ratios, having other siblings in ECE, and Māori or Pacific Island ethnicity were risks. These variables should be included in research into infectious disease-related health outcomes for preschool children.

Meta-analysis published in 2007 by Fisk et al. found that building dampness and mould are associated with increases of 30-50% in a variety of respiratory and asthma-related health outcomes [228]. In a 2017 New Zealand paper by Shorter et al. [216], indoor visible mould was reported to be an important factor in early new onset wheeze in children, with the strongest mould odour and highest levels of mould associated with 13-14 times increased odds of new onset wheezing over those with no mould odour or mould. In the ECEE study 29% of parents reported visible mould in their homes. This prevalence, combined with the consistently elevated winter and spring rate ratios for illness risk associated with visible mould, indicate that building mould should be treated as an important factor in child respiratory morbidity.

Child health history data was used to describe the cohort, but could not be used to assign cause of illness. It would be of value if the ECEE study was later compared to another similar study with similar descriptive variables. If the study power was sufficient, it would also provide the ability to compare outcomes for children with differing health histories.

7.6 Limitations

7.6.1 Study power

The first limitation of the study was scale. Due mainly to the 30% enrolment rate, the final child data set was only 77% of the estimated cohort size of 284 children in the study power calculation, despite good retention.

The volume of work involved in maintaining data flow from the centre managers and parents was at the limit of a single-researcher project, however. It could have become unmanageable if the cohort had been as large as hoped for. This limitation had two effects:

1. It made the study data more vulnerable to unusual centre conditions, as exemplified by the outlier described in Section 6.5.2, and unexpected correlations such as that between mould in home score and childcare centre crowding.

2. It limited the analysis to the largest outcome set, child sick days, rather than allowing regression analysis for subsets of illness, such as respiratory illnesses.

7.6.2 Limitations of environmental measurements

Occupancy and crowding

The study did not measure the number of children indoors, as children can normally move freely between indoors and outdoors for most of the day in New Zealand ECE centres. The occupancy rates were derived from Ministry of Education attendance data (recorded daily), so they are only representative of children at the centre, rather than inside the building. This limitation may have distorted space per child measurements, and consequently distorted the calculation of illness rates in relation to space per child.

The problem could be resolved in a subsequent study by counting entries and exits through doors to give an accurate measure of area per person. The technical difficulty in this approach is that sensors would need to be able to determine the direction of movement, into the space or out of the space, to produce a count of people in the space.

Temperature variation by height

It would have been useful to measure temperature at adult height, although this would have required twice the number of sensors. Higher temperatures at adult head height may have affected teacher perceptions of temperature, and could constitute a possible influence on low temperatures at child height.

Ventilation

The study did not have accurate measures of ventilation rates, and was restricted to CO_2 as a proxy for ventilation. Unfortunately, equipment and funding were not available for sufficient

CO_2 monitors to enable monitoring of activity spaces. Observations during the study, combined with CO_2 data from sleep rooms, suggested that monitoring the opening of windows would be useful. The ENVIRH study had also observed a lack of use of openable windows, and that indoor CO_2 levels were inversely proportional to opening windows and internal doors, and higher wind velocity. In that study, 33% of childcare centres were observed to have windows open during CO_2 monitoring period [185].

Parental work and sick leave demand

The study did not ask parents about their normal work demands – as employees, self-employed, or not in paid employment. The sick leave demand of 4.5 days median and 5.5 days average during the winter-spring half-year was only for parents who had to take some time off paid employment. It did not take into account parents in paid employment whose children were not sick, so the calculation is not representative of the overall risk for parents in paid employment.

Having said this, it is difficult to get an accurate measure of the risk to employment, because of the variability of alternative sick-child carer options, such as other family members.

7.6.3 Limitations of illness data

The study used 'serious enough that a child wouldn't attend if it was a normal attendance day' as the threshold for counting an illness (including weekends). In some cases, non-attendance was the parent's decision, while in others it was the decision of centre management. The weakness in this approach is that there was no standard for exclusion consistently applied, even across centre management. The study confirmed that parents bringing sick children can be a problem (see Section 6.2.6), and that some centres were allowing sick children to attend. These children would not have been counted as sick, so the sick day count and illness event counts are likely to be conservative.

It would not have been possible to account for children attending while sick, as that would have required another threshold based on more marginal symptoms. It would also have more work by centre managers to assess and describe illnesses in children who were attending while sick. Aside from legal problems associated with acknowledging sick child attendance, during the study it became increasingly difficult to obtain even the simple weekly presence/absence report from centre managers

The use of symptomatic illness data provided by parents, rather than diagnosis by a physician, meant that the infectious agents could not be identified (except in the case of chickenpox). There are substantial differences in the responses of bacteria, viruses and protozoa to environmental conditions. Warmer room temperature conditions are likely to favour bacterial growth, but virus and cyst-forming protozoa such as Giardia do not multiply in the environment. As discussed in Section 7.4, cooler temperatures are likely to favour viral survival.

7.6.4 Limitations of home data

Data describing home environment conditions such as presence of mould were reported by parents on a simple 0–3 Likert scale, and crowding was approximated by person to bedroom ratio. There were no home visits by researchers, and consequently no empirical measurement of home temperatures, area, or mould.

7.6.5 Sample skewing and selection bias

The child cohort was slightly skewed for gender (more girls than boys), but in regression analysis gender had a small but significant effect, but the effect size was small. It did not appear as a variable affecting illness outcomes.

The voluntary nature of the study produced potential selection bias. The sample of childcare centres was limited to those organisations (or centre managers) willing to participate. Reasons for not enrolling included concerns about study implications and staff stress, both of which could be related to conditions in the centre(s). The parents who enrolled their children were those willing and/or able to give some time to the study.

7.6.6 Centre type

The ECEE study was limited to one type of ECE centre: full-day childcare centres. Full-day childcare operates under the same legislation as other types, with the exception of home-based care, but differences in results could arise from differences in hours of attendance per day, demographic differences such as ethnicity, and the design and size of outdoor spaces.

7.7 Study methods

7.7.1 Illness data collection from parents

The study demonstrated that it is feasible to gather this information directly from parents, and that direct entry of data on a website is viable. The use of website data entry avoided the need for transcribing handwritten responses, and by using data entry controls, largely avoided incomplete data entries. Having said this, the system could by no means be set up and left to run. Parents required a substantial amount of follow-up. Few parents entered data without any prompting, and it was common for parents to ignore a first-time text message reminder. The process of contacting centres for weekly data, maintaining tracking systems, and contacting parents for the initial process and then follow-up data, was in the region of half to two-thirds of a full-time job. It would be realistic to suggest that the staff demand for this method of data-gathering is about one full-time role per 300 children, spread over 7 days a week, with much of that time in evenings and weekends.

The introductory process with the parents (login and background questionnaires) was very important, and needed to be done with a researcher on the phone as it was difficult to anticipate all questions parents might have.

During the study, good tracking systems proved invaluable, not only for children's illnesses and absences, but also for communication with parents. When centres provided weekly reports of children's absences, the data were entered on a spreadsheet calendar, so that missing data could not only be tracked, but described to parents, for example, "The centre said Sophie was away the week beginning 18 August, and then again the week beginning

1 September." When a few weeks had elapsed between the illness and successful follow-up contact, it was not unusual for parents to have forgotten the dates of the children's illnesses, especially if leave from work was not required. This tracking system also provided a constant check on follow-up progress, used in conjunction with website reports that showed details of data entry by parents (login dates and responses).

Smartphone technology was a great advantage, because it allowed tracking of attempts to contact parents, as well as text information. Phone numbers were tagged with the child's ID, parent's name, and the child's name (for example 018 Rebecca for POLLY), to enable appropriate response to incoming calls. The quality of conversation tracking was important, so that the researcher could be aware of any important events, such as a bereavement or a parent's illness, and exercise appropriate sensitivity.

It was also important to allow for a small number of parents to have no internet access, or to have system failures (e.g. computer failure or lost devices). During the ECEE study eight parents required proxy login by the researcher, with parents providing information by phone.

7.7.2 Environmental monitoring

The Wireless Tags selected as the temperature and humidity monitoring devices were a good design for this application, as they were small and able to be well secured to a wall, door-frame, or to furniture. As described in Section 5.3.3, they required modification because the airflow to the sensor was inadequate to provide quick response times. The modification (a 4mm hole drilled in the cover) was easy to do and caused no problems.

The biggest problem experienced with this system was an incompatibility of Vodafone SIM cards (used in the wireless routers) with the Tag Managers. The initial trial of the devices and calibration had been done with Spark SIM cards with no problems, but as the University of Otago data contract was with Vodafone, Vodafone was the supplier of choice for the full six-month deployment. Unsuccessful attempts to resolve this technical problem with Vodafone resulted in much wasted time, and prevented deployment of the Tags until just before the start of the illness data-gathering period. The solution was to use another SIM card and data provider, 2 Degrees (provided from a BRANZ data contract), but the delay meant that the reliability of the full deployed system, with 58 Tags and 21 Tag Managers, had not been tested prior to the main data-gathering period.

The other problems experienced were mainly a combination of system downtime due to a failure to reset a Residual Current Device, combined with faults in Wireless Tag notification systems. It may be that if there had been sufficient field trial time for the full system, these latter problems could have been resolved.

I would recommend the Wireless Tags system as a viable option for research in ECE settings, but full field trials will be important well before any critical data-gathering period.

7.7.3 Centre manager stress and respondent fatigue – implications for study design and duration

During Phase Two of the study I became aware of high stress levels among the managers of the enrolled centres. My last experience of frequent ECE centre visiting was 2004–09, in a Public Health role, and it seemed to me that teacher stress levels had increased in the seven-year intervening period. As the study progressed, I identified seven of the twenty-one centre managers as seeming to be very stressed, and of those seven, three (all teachers) left their roles by the end of the study. I followed up these managers after they left their workplaces, and in each case, they confirmed stress as a contributing factor in leaving their employment. During the data-gathering phase it was not uncommon to receive weekly absence reports at 9pm, or on a Sunday afternoon. One manager apologised when sending a late evening response, “Sorry Mike, another twelve hour day.”

As the data-gathering process progressed into the fourth and fifth months, it became harder to elicit responses from parents, and the weekly centre reports were increasingly late, with reminders needed. From this experience I suggest that four months may be a realistic limit for this system of data-gathering, and that every effort should be made to keep time demand on ECE centre staff to a minimum.

7.7.4 Management of confidentiality for findings of non-compliance

The findings of substantial non-compliance with Ministry of Education requirements, and in particular the finding of incorrect space measurement by Ministry of Education officials, required sensitive handing. All centres were informed of their own environmental results. Centres that had substantial breaches of regulations were informed that the overall results of the study would be conveyed to the Ministry of Education, including problems with measurement of spaces, but were assured that, consistent with the confidentiality agreement in the enrolment forms, the identity of centres in the study would not be provided to the Ministry of Education.

7.8 Conclusions – hypothesis and study methods

The ECEE study has provided a baseline for New Zealand ECE and care environmental research, providing some measures of illness rates and parental lost work time, and an operational sample of temperatures and crowding rates in childcare centres. It has also demonstrated both the viability and the time costs of gathering illness data directly from parents, using website-based data entry by parents, but with the limitation that four months may be a reasonable limit for a study using this method.

The childcare centre cohort had serious breaches of compliance with environmental legal standards for temperatures and space per child, and issues with poor ventilation of sleep rooms. The study also found that illness rates in the child cohort were likely to place a strain on parental sick leave allowances. The results are likely to be generalisable to childcare centres in other parts of New Zealand, with the proviso that local climatic conditions, especially in warmer areas, may reduce heating demands and the frequency of cold indoor temperatures. The illness rates recorded are likely to be generalisable to other areas of New Zealand, but are likely to be conservative due to attendance by sick children.

The results provide evidence of a significant negative relationship between temperatures and illness rates, with a decrease in illness rates of 25% to 28% for each degree increase in the upper-teen temperature range. The findings support an increase in the minimum temperature for ECE environments for the purpose of reducing illness rates.

The study did not find a relationship between RH or AH and illness rates using linear regression. The results are consistent with viral pathogen infectivity in the environment. The study did not find evidence for crowding causing an increase in illness rates, but there was a positive association between greater illness rates and more space, contrary to other research found in the literature review. This may have been due to the use of daily attendance data as a proxy for room loading, without information as to whether children were indoors or outdoors, and multicollinearity.

The child cohort was insufficient for in-depth analysis of illness types. A larger study, repeating and refining the ECEE study, could provide more detailed analysis of illness types, and, with a modification of methods, a better measure of indoor space per child. Further research is needed into building design and environmental conditions, especially in relation to heating and ventilation.

7.9 ECE sector policy developments

As can often happen during a three-year research programme, the policy, political and professional landscape changed substantially during the ECEE study. While the data-gathering was under way in 2017, New Zealand had a change of government, and that government began a review of early childhood education and care. In November 2018 the government released the Draft Strategic Plan for Early Learning 2019–29: Draft for Consultation [229]. The vision statement included quality of life:

"New Zealand's early learning system enables every child to enjoy a good life, learn and thrive in high quality settings…"

The plan has five goals, with the first goal being:

"Quality is raised for children by improving regulated standards."

The ECEE study provides evidence to support a change in the minimum temperature standard. Along the way, it gathered information about other indicators and influencers of quality, such as teacher hygiene practices and teacher stress, and related technical data, such as types of heating systems in use, and (if only by CO_2 as a proxy), ventilation, which will be useful when considering regulation change and ECE sector policy. The consultation process for the draft strategic plan offers an excellent opportunity to contribute to regulatory change based on very recent quantitative research.

8 Recommendations for research, and for health, education and employment policy

I would like to make a number of recommendations following the ECEE study experience and results. These recommendations also draw on my own experience with the ECE and care sector since 1992, as well as active engagement with ECE teacher discussions during 2016–18.

Some of the recommendations would be best implemented by BRANZ and/or other research organisations dealing with building technology. Examples are research into ventilation of buildings used for ECE and care, and which heating technologies may best assist centres to achieve better indoor temperatures. Recommendations are also described in Appendix 15 for education, health and employment policy that will form part of a response to the draft Strategic Plan for Early Learning 2019–29, for which submissions are due by 15 March 2019.

8.1 Key recommendations for policy

There are three key recommendations to improve child and teacher health from the study findings:

1. Increase the minimum temperature for early childhood centres to 18°C, accompanied by research into cost-effective heating technology and support for retro-fitting of improved systems in existing centres.

2. Improve the monitoring and enforcement of minimum standards for temperatures and crowding in early childhood centres.

3. Develop and implement enforceable requirements for adequate ventilation in early childhood centres.

The study also indicates that:

4. Reducing mould in New Zealand homes should be treated as a priority for child and adult health.

5. The minimum sick leave allowance of 5 days per year should be increased to enable parents to care for sick children, and to reduce pressure on early childhood centres to allow sick child attendance.

8.2 Improvements to the ECEE study methods

If another study similar to the ECEE study is conducted, I recommend the following improvements:

1. Increasing the centre and child cohort size, but restricting the study length to a maximum four months.
2. Tracking of actual room loading by recording entry to and exit from rooms.
3. Recording ventilation measures, for example CO_2 levels in both sleep and activity spaces.
4. Recording the age of a child when they first attended group ECE and care, including first-time enrolment over two years of age.
5. Recording parents' paid work situation – at least whether they are in paid employment or not.
6. As far as practicable, engaging with centres to standardise exclusion criteria for sick children, at least for the study period.

8.3 Research practice in the ECE setting

Management, teacher and parent stress

The ECEE study revealed stress among the childcare centre cohort managers and teachers, and the 2014–18 research by Sarah Alexander of Child Forum and 2017 research by Susan Bates showed that stress is present across the ECE and care sector. Research in the sector will need to respect these pressures, and try to avoid administrative loading of teachers that could increase stress.

During the data-gathering period it was also evident that parents were experiencing time pressure. Research methods engaging parents will need to include an element of patient engagement, with a need to be flexible enough to accommodate parent schedules including mid-to-late evening and weekend options for phone calls.

Website-based data-gathering and associated systems

I recommend the use of website-based data entry by parents, but with the proviso that there needs to be a back-up system for proxy login by a researcher, and very good supporting systems to track communication and data entry.

Wireless Tags for environmental monitoring

I can give a cautious recommendation for the use of the Wireless Tags system in this setting because of the size of the devices and the ability to secure them at child height, but strongly recommend a full system trial period to ensure that the Tag performance-monitoring systems are working. An assessment of the need for Residual Current Device protection would be helpful, as the manual re-setting of these devices caused loss of data.

Parental work and sick leave demand

The study did not ask parents about their normal work demands – as employees, self-employed, or not in paid employment. The sick leave demand of 4.5 days median and 5.5 days average during the winter-spring half-year was only for parents who had to take some time off paid employment. It did not take into account parents in paid employment whose children were not sick, so the calculation is not representative of the overall risk for parents in paid employment.

Having said this, it is difficult to get an accurate measure of the risk to employment, because of the variability of alternative sick-child care such as other family members.

8.4 Research topics

The following topics would be useful to pursue in further research:

1. A study repeating the objectives of the ECEE study, enrolling children under two years old.
2. A study repeating the objectives of the ECEE study, extended to other types of ECE service, such as Kōhanga Reo or Free Kindergartens.
3. An assessment of existing ventilation and CO_2 levels in ECE centres (see Section 7.9 for concurrent research).
4. Research into efficient and effective heating (and ventilation) options for the ECE and care setting, including infrared systems, underfloor heating, and air curtains. This could include intervention studies, possibly with supplier sponsorship.
5. Research into cost-effective and practical mechanisms for monitoring and logging temperatures and air quality in all ECE centres.
6. Research into teacher knowledge of health and hygiene, and an assessment of teacher training for those knowledge areas.
7. A study of microbiological survival on surfaces in ECE environments, including viral, bacterial, and protozoan survival.
8. A study of early childhood teacher illness rates and sick leave use (as well as sick leave provisions).

8.5 ECE Strategic Plan 2019–29

The draft strategic plan identifies three goals relevant to this research:

Goal 1: Quality is raised for children by improving regulated standards.

Goal 3: Investment in our workforce supports excellence in teaching and learning.

Goal 5: The early learning system continues to innovate, learn and improve.

Appendix 16 contains detailed recommendations from this thesis to be included in a submission to the Ministries of Education and Health in response to the draft plan.

References

1. Ministry of Education, *Te Whāriki, He Whāriki Mātauranga mō ngā Mokopuna o Aotearoa - Early Childhood Curriculum*. 1996, Wellington, New Zealand: Learning Media Limited.
2. May, H., *Concerning Women, Concerning Children*. 2003, Wellington, New Zealand: Te Tari Puna Ora O Aotearoa - New Zealand Childcare Association.
3. Meade, A. and V.N. Podmore *Early Childhood Education Policy Co-ordination under the Auspices of the Department/Ministry of Education: A Case Study of New Zealand*. 2002.Available from: http://unesdoc.unesco.org/images/0011/001102/110281e.pdf
4. May, H. and L. Mitchell *Strengthening Community-based Early Childhood Education in Aoteoroa New Zealand : Report of the Quality Public Early Childhood Education (QPECE) Project 2009* 2009.Available from: http://www.nzare.org.nz/portals/306/images/Files/May%20and%20Mitchell%20(2009)%20Report_QPECE_project.pdf
5. Early Childhood Council. *ECC Philosophy*. Early Childhood Council 2018 [29/11/18]. Available from: https://www.ecc.org.nz/aboutus/Category?Action=View&Category_id=504
6. Ministry of Health, *Nga kupu oranga - Healthy messages*, M.o. Health, Editor. 1997: Wellington New Zealand.
7. Regional Public Health (Wellington), *The New Centres Pack*. 2000, Hutt Valley District Health Board: Lower Hutt, New Zealand.
8. City of Helsinki. *Family Day Care*. City of Helsiki 2018; Available from: https://www.hel.fi/helsinki/en/childhood-and-education/day-care/family/
9. Daycare.com, *State Definition of Licensed Family Child-Care Homes*, in *Daycare.com*. 2018.
10. Marx, J., D.J. Osguthorpe, and G. Parsons, *Day Care and the Incidence of Otitis Media in Young Children.* Otolaryngology- Head and Neck Surgery, 1995. **112**(6): p. 695-699. https://dx.doi.org/10.1016/S0194-59989570178-8
11. Bedford, M., *A needs assessment of early childhood centres with respect to non vaccine-preventable communicable diseases.* 1999.
12. Ministry of Education. *Understanding attendance; results from the 2017 Early Childhood Education census*. 2018; Available from: https://www.educationcounts.govt.nz/publications/series/annual-early-childhood-education-census/understanding-attendance-results-from-the-2017-early-childhood-education-census
13. Stats New Zealand. *Historical population estimates tables*. Stats NZ, Archives 2018 [25/6/18]. Available from: http://archive.stats.govt.nz/browse_for_stats/population/estimates_and_projections/historical-population-tables.aspx
14. Baker, M.G., et al. *Infectious diseases attributable to household crowding in New Zealand: A systematic review and burden of disease estimate*. 2013; Available from: http://www.healthyhousing.org.nz/wp-content/uploads/2010/01/HH-Crowding-ID-Burden-25-May-2013.pdf

15. Howden-Chapman, P., et al., *Effect of insulating existing houses on health inequality: Cluster randomised study in the community.* British Medical Journal, 2007. **334**(7591): p. 460-464. https://dx.doi.org/10.1136/bmj.39070.573032.80

16. NZ Playcentre Federation. *Playcentre*. 2019; Available from: https://www.playcentre.org.nz

17. Ministry of Education. *Education Counts*. Participation 2017; Available from: http://www.educationcounts.govt.nz/statistics/early-childhood-education/participation

18. Ministry of Education. *Education Statistics of New Zealand for 2005*. 2006; Available from: https://www.educationcounts.govt.nz/__data/assets/pdf_file/0007/7684/2005-Education-Statistics-of-NZ-Booklet.pdf

19. Ministry of Education. *Education Statistics of New Zealand for 1993*. 1994; Available from: https://www.educationcounts.govt.nz/__data/assets/pdf_file/0011/7130/1993-Education-Statistics-of-NZ-Booklet.pdf

20. Ministry of Education. *Education Counts*. Enrolments - Participation in ECE 2018 [25/6/18]. Available from: https://www.educationcounts.govt.nz/statistics/early-childhood-education/participation

21. NZ Families Commission. *Paid Parental Leave – Issues for Today's Economic Times* 2010; Available from: http://thehub.superu.govt.nz/assets/documents/Paid-Parental-Leave_(Issues-paper-4).pdf

22. Inland Revenue. *For individuals & families - Paid parental leave*. 2018; Available from: https://www.ird.govt.nz/yoursituation-ind/parents/parents-paid-parental-leave.html

23. Stats New Zealand. *Social Indicators*. Stats NZ 2018; Available from: http://archive.stats.govt.nz/browse_for_stats/snapshots-of-nz/nz-social-indicators/Home/Standard%20of%20living/housing-affordability.aspx

24. Ministry of Education. *Licensing Criteria for Early Childhood Education & Care Services 2008 and Early Childhood Education Curriculum Framework*. 2018; Available from: https://www.education.govt.nz/assets/Documents/Early-Childhood/Licensing-criteria/ECE-Licensing-Booklet-Early-Childhood-Aug2018.pdf

25. Toi Te Ora Public Health. *Early Childhood Centres*. Toi Te Ora Public Health 2018 [7/12/18]. Available from: https://www.toiteora.govt.nz/ecc

26. Regional Public Health. *Licensing health reports*. Regional Public Health 2018 [8/12/18]. Available from: http://www.rph.org.nz/public-health-topics/early-childhood-centres/licensing-health-reports/

27. Education Review Office. *Return times for centre and home-based early childhood service reviews*. 2018 [7/12/18]. Available from: https://www.ero.govt.nz/how-ero-reviews/ero-reviews-of-early-childhood-services-and-kohanga-reo/return-times-for-early-childhood-service-reviews/

28. Organisation for Economic Cooperation and Development (OECD). *Encouraging Quality in Early Childhood Education and Care (ECEC), International Comparison: Minimum Standards*. 2011; Available from: http://www.oecd.org/education/school/48483436.pdf

29. Kawai, K. *Effect of sound absorption on indoor sound environment of nursery school classrooms*. in *20th International Congress on Acoustics 2010, ICA 2010 - Incorporating Proceedings of the 2010 Annual Conference of the Australian Acoustical Society*. 2010. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84869119638&partnerID=40&md5=aa89e86efadbbb169821b86de7226342

30. Wikipedia. *Lombard effect*. 2018 [30/11/18]. Available from: https://en.wikipedia.org/wiki/Lombard_effect

31. McLaren, S.J., *Noise in early childhood education centres - the effect on the children and their teachers*, in *School of Health Sciences*. 2008, Massey University, Wellington.

32. Vermeer, H.J., et al., *Downregulation of the immune system in low-quality child care: The case of Secretory Immunoglobulin A (SIgA) in toddlers.* Physiology and Behavior, 2012. **105**(2): p. 161-167. https://dx.doi.org/10.1016/j.physbeh.2011.08.017

33. *Minimum Standards for Day Care Centers and Nighttime Centres Regulations and Proceedures*. 2009 [5/2/19]. Available from: http://dhr.alabama.gov/documents/MinimumStandards_DayCare.pdf

34. *New York State Child Day Care Regulations*. 2017 [5/2/19]. Available from: https://ocfs.ny.gov/main/childcare/regs/416-GFDC.pdf

35. Indiana Department of Child Services. *Indiana administrative code - Child welfare services*. 2003 [5/2/19]. Available from: https://www.in.gov/fssa/files/Rule4.7.pdf

36. Joint Committeee on Administrative Rules. *Social Services Chapter III: Deopartment of Children and Family Services Subchapter e: Requirements for Licensure Part 407 Licensing Standards for Day Care Centres* Title 89 2019 [5/2/19]. Available from: ftp://www.ilga.gov/jcar/admincode/089/089004070H03700R.html

37. Department of Children Youth and Families. *Washington State Daycare Licensing Requirements*. 2016 [Chapter 170-295 WAC]. Available from: https://osse.dc.gov/sites/default/files/dc/sites/osse/publication/attachments/Final%20Rulemaking%20for%20the%20Licensing%20of%20Child%20Development%20Facilities_0.pdf

38. Colorado Department of Health and Environment. *Rules and regulations governing the health and sanitation of child care facilities in the State of Colorado, 6 CCR 1010-7*. 2016 [5/2/19]. Available from: https://www.colorado.gov/pacific/sites/default/files/DEHS_ChildCare_6CCR1010-7_DistribCopy_Jan2016.pdf

39. Division of Licensing and Regulatory Services - Community Services Programs. *Rules for the Licensing of Child Care Facilities*. 2008; Available from: https://www.maine.gov/sos/cec/rules/10/148/148c032.doc

40. Arizona Department of Health Services Bureau of Child Care Licensing. *Arizona administrative code and Arizona revised statutes for child care facilities*. 2018 [6/2/19]. Available from: https://www.azdhs.gov/documents/licensing/childcare-facilities/rules/bccl-child-care-facility-rules.pdf

41. Tennessee Department of Human Services Community and Social Services Division. *Licensure Rules for Child Care Agencies*. 2019; Available from: https://publications.tnsosfiles.com/rules/1240/1240-04/1240-04-01.20190103.pdf

42. Oregon Department of Education Early Learning Division Office of Child Care. *Rules for certified child care centers*. 2017 [6/2/19]. Available from: https://oregonearlylearning.com/wp-content/uploads/2017/02/CRT-132-CC-Rule-book-3-27-17-FINAL.pdf

43. Alberta Health Services. *Health and Safety Guidelines for Child Care Facilities*. 2018 [5/2/19]. Available from: https://www.albertahealthservices.ca/assets/wf/eph/wf-eh-health-safety-guidlines-child-care-facilities.pdf

44. *Child Care and Early Years Act 2014: Ontario Regulation 137/15*. 2014 [5/2/19]. Available from: https://www.ontario.ca/laws/regulation/150137#BK22

45. *Educational Childcare Regulation, Chapter S-4.1.1, r. 2*. 2018 [5/2/19]. Available from: http://legisquebec.gouv.qc.ca/en/showdoc/cr/S-4.1.1,%20r.%202

46. National Resource Center for Health and Safety in Child Care and Early Education. *Indoor Temperature and Humidity* Caring for Our Childen (CFOC) 2019 [5/2/19]. Available from: http://nrckids.org/CFOC/Database/5.2.1.2

47. Wisconsin Department of Children and Families - Division of Child Care and Early Childhood Education. *Wisconsin Administratice Code - Licensing Rules for Group Child Care Centers*. 2009; Available from: https://dcf.wisconsin.gov/files/publications/pdf/0205.pd

48. South Dakota Department of Social Services. *Child Care Licensing Policy Handbook*. 2018; Available from: https://dss.sd.gov/docs/childcare/licensing_handbook.pdf

49. Cabinet for Health and Family Services - Department for Community Based Services. *Kentucky Administrative Regulations, Title 922922, KAR 1:300. Standards for child-caring facilities*. 2018 [5/2/19]. Available from: https://apps.legislature.ky.gov/law/kar/922/001/300.pdf

50. Department of Public Health & Human Services - Licensure Bureau - Child Care Licensing. *Licensing Requirements for Child Day Care Centres*. 2012; Available from: https://dphhs.mt.gov/Portals/85/qad/documents/LicensureBureau/ChildCare/DCCRegulationBook.pdf

51. Oklahoma Department of Human Services - Child Care Services. *Licensing Requirements for Child Care Programs*. 2018; Available from: http://www.okdhs.org/OKDHS%20Publication%20Library/14-05.pdf

52. State of Connecticut Office of Early Childhood Division of Licensing and Regulatory Services - Community Services Programs. *Child Care Centers and Group Child Care Homes M-39 REV. 1/77*. 2017 [5/2/19]. Available from: https://www.ct.gov/oec/lib/oec/licensing/childcare/centers_statsregs.pdf

53. Department for Children and Families - Child Development Division. *Child Care Licensing Regulations*. 2016 [6/2/19]. Available from: https://dcf.vermont.gov/sites/dcf/files/CDD/Docs/Licensing/CBCCPP_Regulations_FINAL.pdf

54. Florida Depatment of Children and Families. *Child Care Facility Handbook*. 2017; Available from: www.myflfamilies.com/service-programs/child-care/laws-and-requirements

55. Maryland State Department of Education Division of Early Childhood Development Office of Child Care. *Planning Your Facility - Physical Plant, Materials, and Equipment*. 2012; Available from: https://earlychildhood.marylandpublicschools.org/system/files/filedepot/3/planningyourfacility.pdf

56. Kansas Department of Health and Environment - Division of Public Health, B.o.F.H.C.C.L.P. *Kansas Laws and Regulations for Licensing Preschools and Child Care Centers*. 2018; Available from: http://www.kdheks.gov/bcclr/regs/ccc/Preschools_and_Child_Care_Centers_all_sections.pdf

57. *The Pennsylvania Code - Chapter 3270 Child Day Care Centers*. 3270 2007 [5/2/19]. Available from: https://www.pacode.com/secure/data/055/chapter3270/chap3270toc.html

58. State of Michigan Department of Human Services - Bureau of Children and Adult Licensing. *Licensing rules for child care centers*. 2014 [5/2/19]. Available from: https://www.michigan.gov/documents/dhs/Child_Care_Center_Rules_419095_7.pdf

59. New Hampshire Department of Health & Human Services - Bureau of Licensing and Certification Child Care Licensing Unit. *New Hampshire Childcare Licensing Rules 2017-2027*. 2017; Available from: https://www.dhhs.nh.gov/oos/cclu/documents/he-c4002.pdf

60. Rhode Island Department of Children, Y.a.F. *Child Care Program Regulations for Licensure* 2013; Available from: http://www.dcyf.ri.gov/docs/child_care_regs.pdf

61. Standards Working Group of the Child Care Regulations Implementation Group. *National Standards for Pre-School Services - Full day care services*. 2010 [13.3.2010]. Available from: https://www.dcya.gov.ie/documents/publications/20160510ChildCareActEarlyYrsRegs2016SI221of2016.pdf

62. Department of Health & Social Care. *Child Day Care Centres Minimum Standards*. 2017; Available from: https://www.gov.im/media/1345646/2017-child-day-care-centre-standards-v2.pdf

63. World Health Organization Regional Office for Europe. *Health impact of low indoor temperatures : report on a WHO meeting : Copenhagen, 11-14 November 1985*. 1987; Available from: https://www.worldcat.org/title/health-impact-of-low-indoor-temperatures-report-on-a-who-meeting-copenhagen-11-14-november-1985/oclc/19276717

64. *Education (Early Childhood Centres) Regulations 1990*. Available from: http://www.legislation.govt.nz/regulation/public/1998/0085/latest/whole.html

65. Office of the Revisor of Statutes. *Chapter 9502, Licensing of Day Care Facilities*. Minnesota Administrative Rules 2007 [5/2/19]. Available from: https://www.revisor.mn.gov/rules/9502.0425/

66. *Education (Early Childhood Services) Regulations 2008*. Available from: http://www.legislation.govt.nz/regulation/public/2008/0204/42.0/DLM1412501.html

67. *Education (Early Childhood Centres) Regulations 1998*. Available from: http://www.legislation.govt.nz/regulation/public/1998/0085/latest/whole.html

68. Division of Child Care and Early Childhood Education. *Minimum Licensing Requirements for Child Care Centers*. 2015 [PUB-002 (Rev. 01/01/2015)]. Available from: https://humanservices.arkansas.gov/images/uploads/dccece/2014A1CCC-CleanCopyFinalFiling.pdf

69. Texas Department of Family and Protective Services. *Minimum Standards for Childcare Centers*. Chapter 746, Title 40, Social Services & Assistance, Part 19 2016; Available from: https://www.nrhtx.com/DocumentCenter/View/3276/Minimum-Standards-for-Child-Care-Centers

70. *The Community Child Care Standards Act 1986*. Regulation 62/86 2018 [5/2/19]. Available from: https://web2.gov.mb.ca/laws/regs/current/_pdf-regs.php?reg=62/86

71. *The Child Care Regulations, 2015 Chapter C-7.31 Reg 1, as amended by Saskatchewan Regulations 69/2015, 49/2016 and 21/2018*. 2018 [5/2/19]. Available from: http://www.publications.gov.sk.ca/freelaw/documents/English/Regulations/Regulations/C7-31R1.pdf

72. *Child Care Licensing Regulation, B.C. Reg. 332/2007 includes amendments up to B.C. Reg 188/2018,*.

[5/2/19]. Available from: http://www.bclaws.ca/civix/document/id/complete/statreg/332_2007#part1

73. *Child Care Regulations: 39/17 s1*. 2017 [5/2/19]. Available from: https://www.assembly.nl.ca/legislation/sr/regulations/rc170039.htm#1_

74. Department for Education and Skills. *National standards for under 8s day care and childminding*. 2003 [5/2/19]. Available from: http://www3.imperial.ac.uk/pls/portallive/docs/1/46973696.PDF

75. *Education and Care Services National Regulations 2012* 2011-653 [5/2/19]. Available from: https://www.legislation.nsw.gov.au/#/view/regulation/2011/653

76. Bedford, M., S. Bates, and W. Page. *ECE in New Zealand: A hazard to child and teacher health?* [Youtube video of presentation] 2018; Available from: https://www.youtube.com/watch?v=GD1cNeaoJAM

77. Gerritsen, J. *NZ childcare centres too cold and too noisy, researchers warn*. 2018; Available from: https://www.noted.co.nz/currently/education/nz-childcare-centres-too-cold-and-too-noisy-researchers-warn/

78. Wikipedia. *Oceanic climate*. 2019 [8/1/19]. Available from: https://en.wikipedia.org/wiki/Oceanic_climate

79. Environmental Standard Indexes Ltd. *Radiant heaters*. BS Index - Building Services 2018 [8/12/18]. Available from: https://www.buildingservicesindex.co.uk/category/3-1729/Radiant-heaters/

80. BRANZ. *Radiant heaters*. Level 2018 [8/12/18]. Available from: http://www.level.org.nz/energy/space-heating/radiant-heaters/

81. Bushouse, B.K. *Early Childhood Education Policy in Aotearoa / New Zealand: The Creation of the 20 Hours Free Programme*. Wellington , New Zealand, 2008.Available from: https://www.fulbright.org.nz/wp-content/uploads/2011/12/axford2008_bushouse.pdf

82. Early Childhood Education Taskforce. *An Agenda for Amazing Children: Final Report of the ECE Taskforce*. 2011; Available from: https://books.google.co.nz/books?id=qO5fnQEACAAJ

83. Ministry of Education. *Ministry of Education Statement of Intent 2014-2018*. 2014; Available from: https://www.education.govt.nz/assets/Documents/Ministry/Publications/Statements-of-intent/2014SOI.pdf

84. Cherrington, S. *An open letter to the new education minister on early childhood policies*. 2017; Available from: https://www.newsroom.co.nz/2017/04/25/20679/an-open-letter-to-the-new-education-minister-on-early-childhood-policies#

85. Colliers International. *Childcare centres a growth investment*. 2017 [1/8/18]. Available from: http://www.colliers.co.nz/news/2017/childcare%20centres%20a%20growth%20investment/

86. Berhane, K., et al., *The effect of ambient air pollution on exhaled nitric oxide in the children's health study.* European Respiratory Journal, 2011. **37**(5): p. 1029-1036. https://dx.doi.org/10.1183/09031936.00081410

87. Lyne, M., *Exposure Asessment of Traffic-Related PM10 Pollution in Outdoor Play Areas of Early Childhood Centres*, in *School of Applied Sciences*. 2008, Auckland University of Technology.

88. World Health Organisation *Effects of air pollution on children's health and development - a review of the evidence*. 2012.Available from: http://www.euro.who.int/__data/assets/pdf_file/0010/74728/E86575.pdf

89. Ministry of Health. *An integrated approach to infectious disease - Priorities for action 2002 - 2006*. 2001; Available from: http://www.moh.govt.nz/notebook/nbbooks.nsf/0/178AFE017ED923C5CC256AFD006A254D/$file/integratedapproachtoinfectiousdisease-prioritiesforaction.pdf

90. Ministry of Health. *Child and Youth Health Toolkit : Ensuring access to appropriate child health care services including well child and family health care, and immunisation* 2004; Available from: http://www.moh.govt.nz/notebook/nbbooks.nsf/0/9218213176C0DAABCC25770200751AAF/$file/childandyouthhealthtoolkit.pdf

91. Ministry of Health. *New Zealand health strategy - Roadmap of actions 2016*. 2016; Available from: https://www.health.govt.nz/system/files/documents/publications/new-zealand-health-strategy-roadmapofactions-2016-apr16.pdf

92. Ministry of Health. *Communicable disease control manual*. 2012; Version 3, Revised 2018:[Available from: https://www.health.govt.nz/system/files/documents/publications/communicable-disease-control-manual-may18-v3.pdf

93. Institute of Environmental Science and Research Ltd. *Notifiable Diseases tables by age, sex, ethnic group, 2017*. Annual Notifiable Disease Tables 2018; Available from: https://surv.esr.cri.nz/surveillance/annual_diseasetables.php

94. Addiss, D.G., et al., *Giardia lamblia and Cryptosporidium infections in child day-care centers in Fulton county, Georgia.* Pediatric Infectious Disease, 1991. **10**(12): p. 907-911. https://dx.doi.org/10.1097/00006454-199112000-00005

95. Pickering, L.K., et al., *Occurrence of Giardia lamblia in children in day care centers.* The Journal of Pediatrics, 1984. **104**(4): p. 522-526. https://dx.doi.org/10.1016/S0022-3476(84)80540-5

96. Lal, A., *Epidemiology of Enteric Diseases*, in *Department of Public Health*. 2014, University of Otago. p. 217.

97. Greater Wellington Regional Council. *Water Supply Grading*. Wellington Water 2018 [8/1/19]. Available from: https://www.wellingtonwater.co.nz/your-water/drinking-water/how-is-it-treated/whats-in-your-water/water-supply-grading/

98. Hoque, M.E., et al., *Children at risk of giardiasis in Auckland: A case-control analysis.* Epidemiology and Infection, 2003. **131**(1): p. 655-662. https://dx.doi.org/10.1017/S0950268803008598

99. Gerritsen, J. *It is like factory farming for children*. 2015; Available from: https://www.radionz.co.nz/news/national/286327/'it-is-like-factory-farming-for-children'

100. Child Forum. *Freezing cold early childhood centre – saving centre power bill comes before children*. 2017 [1/8/18]. Available from: https://www.childforum.com/news-early-childhood-education-latest/1542-temperature-centre-heating.html

101. Bates, S. *Susan Bates: Our kids are not getting enough space in childcare*. 2017; Available from: https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11894416

102. Collins, S. *Parents' revolt forces kindergarten backdown*. 2017; Available from: https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11905741

103. Johnston, K. *Quarter of early childhood workers wouldn't enrol their kids*. 2015; Available from: https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11525360

104. Cantrell, M.A. and Lupinacci, P., *Methodological issues in online data collection.* Journal of Advanced Nursing, 2007. **60**(5): p. 544-549. https://dx.doi.org/10.1111/j.1365-2648.2007.04448.x

105. Zhou, Q., et al., *The lock-up phenomenon of exhaled flow in a stable thermally-stratified indoor environment.* Building and Environment, 2017. **116**: p. 246-256. https://dx.doi.org/10.1016/j.buildenv.2017.02.010

106. Allen-Williams, G.M., *Incidence of infections in war-time day nurseries - a preliminary study.* The Lancet, 1945. **246**(6382): p. 825-826. https://dx.doi.org/10.1016/S0140-6736(45)91179-2

107. Pönkä, A., et al., *Infections and other illnesses of children in day-care centers in Helsinki I: Incidences and effects of home and day-care center variables.* Infection, 1991. **19**(4): p. 230-236. https://dx.doi.org/10.1007/BF01644951

108. Nafstad, P., et al., *Day care centers and respiratory health.* Pediatrics, 1999. **103**(4 I): p. 753-758. https://dx.doi.org/10.1542/peds.103.4.753

109. Enserink, R., et al., *Infectious disease burden related to child day care in the netherlands.* Pediatric Infectious Disease Journal, 2013. **32**(8): p. e334-e340. https://dx.doi.org/10.1097/INF.0b013e318290601e

110. Sangrador, C.O., Sánchez, M.V.B, and Martín, B.M., *Relationship between child day-care attendance and acute infectious disease. A systematic review.* Revista Espanola de Salud Publica, 2007. **81**(2): p. 113-129.

111. Nesti, M.M.M., Goldbaum, M., *Infectious diseases and daycare and preschool education.* Jornal de Pediatria, 2007. **83**(4): p. 299-312. https://dx.doi.org/10.2223/JPED.1649

112. Louhiala, P.J., et al., *Form of day care and respiratory infections among Finnish children.* American Journal of Public Health, 1995. **85**(8): p. 1109-1112.

113. Heinrich, J. and Koletzko, B., *Child health and child care in under 3-year-olds.* Monatsschrift fur Kinderheilkunde, 2008. **156**(6): p. 562-568. https://dx.doi.org/10.1007/s00112-007-1607-5

114. Haby, M.M., et al., *Daycare attendance before the age of two protects against atopy in preschool age children.* Pediatric Pulmonology, 2000. **30**(5): p. 377-384. https://dx.doi.org/10.1002/1099-0496(200011)30:5<377::AID-PPUL3>3.0.CO;2-3

115. Lafuente Mesanza, P., et al., *Influence of out-of-home day care on the incidence of infectious processes in 0-3-year-olds.* Anales de Pediatria, 2008. **68**(1): p. 30-38. https://dx.doi.org/10.1157/13114468

116. del Castillo-Aguas, G., et al., *Infectious morbidity and resource use in children under 2 years old at childcare centres.* Journal of Paediatrics and Child Health, 2017. **53**(2): p. 116-122. https://dx.doi.org/10.1111/jpc.13372

117. Haerskjold, A., et al., *Risk factors for hospitalization for respiratory syncytial virus infection.* Pediatric Infectious Disease Journal, 2016. **35**(1): p. 61-65. https://dx.doi.org/10.1097/INF.0000000000000924

118. Mack, I., et al., *Rhinovirus infections and associated respiratory morbidity in infants: A prospective cohort study.* Pediatric Infectious Disease Journal, 2016. **35**(10): p. 1069-1074. https://dx.doi.org/10.1097/INF.0000000000001240

119. Zielhuis, G.A., et al., *Environmental Risk Factors for Otitis Media with Effusion in Preschool Children.* Scandinavian Journal of Primary Health Care, 1989. **7**(1): p. 33-38. https://dx.doi.org/10.3109/02813438909103668

120. Martines, F., et al., *Factors influencing the development of otitis media among Sicilian children affected by upper respiratory tract infections.* Brazilian Journal of Otorhinolaryngology, 2016. **82**(2): p. 215-222. https://dx.doi.org/10.1016/j.bjorl.2015.04.002

121. Greenberg, D., et al., *Acute otitis media in children: Association with day care centers - Antibacterial resistance, treatment, and prevention.* Pediatric Drugs, 2008. **10**(2): p. 75-83. https://dx.doi.org/10.2165/00148581-200810020-00002

122. Alho, O.P., et al., *Risk Factors for Chronic Otitis Media With Effusion in Infancy: Each Acute Otitis Media Episode Induces a High but Transient Risk.* Archives of Otolaryngology--Head and Neck Surgery, 1995. **121**(8): p. 839-843. https://dx.doi.org/10.1001/archotol.1995.01890080011002

123. Hatakka, K., et al., *Factors associated with acute respiratory illness in day care children.* Scandinavian Journal of Infectious Diseases, 2010. **42**(9): p. 704-711. https://dx.doi.org/10.3109/00365548.2010.483476

124. Walker, R.E., et al., *Determinants of chronic otitis media with effusion in preschool children: A case-control study.* BMC Pediatrics, 2017. **17**(1). https://dx.doi.org/10.1186/s12887-016-0767-7

125. Cheng, G., et al., *Duration of day care attendance during infancy predicts asthma at the age of seven: The Cincinnati Childhood Allergy and Air Pollution Study.* Clinical and Experimental Allergy, 2014. **44**(10): p. 1274-1281. https://dx.doi.org/10.1111/cea.12397

126. Pickering, L.K., et al., *Diarrhea caused by Shigella, rotavirus, and Giardia in day-care centers: Prospective study.* The Journal of Pediatrics, 1981. **99**(1): p. 51-56. https://dx.doi.org/10.1016/S0022-3476(81)80956-0

127. Bartlett, A.V., et al., *Diarrheal illness among infants and toddlers in day care centers. I. Epidemiology and pathogens.* The Journal of Pediatrics, 1985. **107**(4): p. 495-502. https://doi.org/10.1016/S0022-3476(85)80004-4

128. Özdemir, S.D., Delialioglu, N., Emekdaş, G., *Investigation of rotavirus, adenovirus and astrovirus frequencies in children with acute gastroenteritis and evaluation of epidemiological features.* Mikrobiyoloji Bulteni, 2010. **44**(4): p. 571-578.

129. Sattar, S.A., et al., *Institutional outbreaks of rotavirus diarrhoea: Potential role of fomites and environmental surfaces as vehicles for virus transmission.* Journal of Hygiene, 1986. **96**(2): p. 277-289. https://dx.doi.org/10.1017/S0022172400066055

130. Rosie, B., et al., *Epidemiology of intussusception in New Zealand pre-rotavirus vaccination.* The New Zealand medical journal, 2016. **129**(1442): p. 36-45.

131. Sealy, D.P. and Schuman, S.H., *Endemic giardiasis and day care.* Pediatrics, 1983. **72**(2): p. 154-158.

132. Enserink, R., et al., *Risk factors for gastroenteritis in child day care.* Epidemiology and Infection, 2015. **143**(13): p. 2707-2720. https://dx.doi.org/10.1017/S0950268814003367

133. Hurwitz, E.S., et al., *Risk of respiratory illness associated with day-care attendance: A nationwide study.* Pediatrics, 1991. **87**(1): p. 62-69.

134. Schuez-Havupalo, L., et al., *Daycare attendance and respiratory tract infections: A prospective birth cohort study.* BMJ Open, 2017. **7**(9). https://dx.doi.org/10.1136/bmjopen-2016-014635

135. Enserink, R., et al., *Transient and sustained effects of child-care attendance on hospital admission for gastroenteritis.* International Journal of Epidemiology, 2015. **44**(3): p. 988-997. https://dx.doi.org/10.1093/ije/dyv073

136. Shope, T.R., *Infectious diseases in early education and child care programs.* Pediatrics in Review, 2014. **35**(5): p. 182-193. https://dx.doi.org/10.1542/pir.35-5-182

137. Hägerhed Engman, L., et al., *Day-care attendance and increased risk for respiratory and allergic symptoms in preschool age.* Allergy: European Journal of Allergy and Clinical Immunology, 2006. **61**(4): p. 447-453. https://dx.doi.org/10.1111/j.1398-9995.2006.01031.x

138. Côté, S.M., et al., *Short- and long-term risk of infections as a function of group child care attendance: An 8-year population-based study.* Archives of Pediatrics and Adolescent Medicine, 2010. **164**(12): p. 1132-1137. https://dx.doi.org/10.1001/archpediatrics.2010.216

139. Immunisation Advisory Centre. *Rotavirus*. The Immunisation Advisory Centre 2017 [19/9/18]. Available from: http://www.immune.org.nz/sites/default/files/resources/Written%20Resources/DiseaseRotavirusImac20170817V02Final.pdf

140. Araújo-Martins, J., et al., *Environment and Health in Children Day Care Centres (ENVIRH) - Study rationale and protocol.* Revista Portuguesa de Pneumologia, 2014. **20**(6): p. 311-323. https://dx.doi.org/10.1016/j.rppneu.2014.02.006

141. La Rosa, G., et al., *Viral infections acquired indoors through airborne, droplet or contact transmission.* Annali dell'Istituto Superiore di Sanita, 2013. **49**(2): p. 124-132. https://dx.doi.org/10.4415/ANN-13-02-03

142. Bell, D.M., et al., *Illness associated with child day care: A study of incidence and cost.* American Journal of Public Health, 1989. **79**(4): p. 479-484. https://dx.doi.org/10.2105/AJPH.79.4.479

143. Trenholme, A., et al., *Household characteristics of children under 2 years admitted with lower respiratory tract infection in Counties Manukau, South Auckland.* New Zealand Medical Journal, 2012. **125**(1367): p. 15-23.

144. Fiedler, K. and Hoyer, H., *Logistic regressions analysis in respect of the influence of childrens-facility, residential environment, residential hygiene, and way of life on the number and duration of acute respiratory diseases of small children.* Zentralblatt fur Hygiene und Umweltmedizin, 1996. **198**(3): p. 204-214.

145. Alexandrino, A.S., et al., *Risk factors for respiratory infections among children attending day care centres.* Family Practice, 2016. **33**(2): p. 161-166. https://dx.doi.org/10.1093/fampra/cmw002

146. Rindel, A.K., et al., *Significance of playroom area for illness among children in daycare centres.* Ugeskrift for Laeger, 1997. **159**(42): p. 6205-6210.

147. Rindel, A.K., Kronborg, D. and Jensen, S.T., *Morbidity of children attending day care centers in Copenhagen illustrated by social, physical, environmental and hygienic factors.* Ugeskrift for Laeger, 1992. **154**(31): p. 2140-2146.

148. Kirkeby, I.M. and Grangaard, S., *Can we build inclusion?* Studies in Health Technology and Informatics, 2016. **229**: p. 246-255. https://dx.doi.org/10.3233/978-1-61499-684-2-246

149. Mygind, O., et al., *Comparative intervention study among Danish daycare children: The effect on illness of time spent outdoors.* Scandinavian Journal of Public Health, 2003. **31**(6): p. 439-443. https://dx.doi.org/10.1080/14034940310005349

150. Morawska, L., *Droplet fate in indoor environments, or can we prevent the spread of infection?* Indoor Air, 2006. **16**(5): p. 335-347. https://dx.doi.org/10.1111/j.1600-0668.2006.00432.x

151. Sobsey, M. and Meschke J. S., *Virus Survival in the Environment with Special Attention to Survival in Sewage Droplets and Other Environmental Media of Fecal or Respiratory Origin*. 2003.Available from: https://www.researchgate.net/publication/228551421_Virus_Survival_in_the_Environment_with_Special_Attention_to_Survival_in_Sewage_Droplets_and_Other_Environmental_Media_of_Fecal_or_Respiratory_Origin

152. Chen, Z., et al., *Association of meteorological factors with childhood viral acute respiratory infections in subtropical China: An analysis over 11 years.* Archives of Virology, 2014. **159**(4): p. 631-639. https://dx.doi.org/10.1007/s00705-013-1863-8

153. Cui, B., et al., *Viral aetiology of acute respiratory infections among children and associated meteorological factors in southern China.* BMC infectious diseases, 2015. **15**: p. 124. https://dx.doi.org/10.1186/s12879-015-0863-6

154. Jevons, R., et al., *Minimum indoor temperature threshold recommendations for English homes in winter – A systematic review.* Public Health, 2016. **136**: p. 4-12. https://dx.doi.org/10.1016/j.puhe.2016.02.007

155. Metz, J.A. and Finn, A., *Influenza and humidity - Why a bit more damp may be good for you!* Journal of Infection, 2015. **71**(S1): p. S54-S58. https://dx.doi.org/10.1016/j.jinf.2015.04.013

156. Paynter, S., *Humidity and respiratory virus transmission in tropical and temperate settings.* Epidemiology and Infection, 2015. **143**(6): p. 1110-1118. https://dx.doi.org/10.1017/S0950268814002702

157. Yeargin, T., et al., *The survival and inactivation of enteric viruses on soft surfaces: A systematic review of the literature.* American Journal of Infection Control, 2016. **44**(11): p. 1365-1373. https://dx.doi.org/10.1016/j.ajic.2016.03.018

158. Zarkov, I.S. and Urumova, V.S., *Effects of humidity and temperature on avian influenza virus H6N2 persistence in faecal samples from experimentally infected ducks (Anas platyrynchos).* Revue de Medecine Veterinaire, 2013. **164**(7): p. 343-347.

159. Shaw Stewart, P.D., *Seasonality and selective trends in viral acute respiratory tract infections.* Medical Hypotheses, 2016. **86**: p. 104-119. https://dx.doi.org/10.1016/j.mehy.2015.11.005

160. Pierse, N., et al., *Modelling the effects of low indoor temperatures on the lung function of children with asthma.* Journal of Epidemiology and Community Health, 2013. **67**(11): p. 918-925. https://dx.doi.org/10.1136/jech-2013-202632

161. Brągoszewska, E., Mainka, A., and Pastuszka, J.S., *Bacterial aerosols in an urban nursery school in Gliwice, Poland: a case study.* Aerobiologia, 2016. **32**(3): p. 469-480. https://dx.doi.org/10.1007/s10453-015-9419-x

162. Prussin, A.J., II, et al., *Seasonal dynamics of the airborne bacterial community and selected viruses in a children's daycare center.* PLoS ONE, 2016. **11**(3). https://dx.doi.org/10.1371/journal.pone.0151004

163. Mendes, A., et al., *Environmental and ventilation assessment in child day care centers in Porto: The envirh project.* Journal of Toxicology and Environmental Health - Part A: Current Issues, 2014. **77**(14-16): p. 931-943. https://dx.doi.org/10.1080/15287394.2014.911134

164. Ibfelt, T., et al., *Presence of Pathogenic Bacteria and Viruses in the Daycare Environment.* Journal of environmental health, 2015. **78**(3): p. 24-29.

165. Dales, R., et al., *Airborne endotoxin is associated with respiratory illness in the first 2 years of life.* Environmental Health Perspectives, 2006. **114**(4): p. 610-614. https://dx.doi.org/10.1289/ehp.8142

166. Li, Y., et al., *Role of ventilation in airborne transmission of infectious agents in the built environment - A multidisciplinary systematic review.* Indoor Air, 2007. **17**(1): p. 2-18. https://dx.doi.org/10.1111/j.1600-0668.2006.00445.x

167. Carreiro-Martins, P., et al., *Effect of indoor air quality of day care centers in children with different predisposition for asthma.* Pediatric Allergy and Immunology, 2016. **27**(3): p. 299-306. https://dx.doi.org/10.1111/pai.12521

168. Kolarik, B., et al., *Ventilation in day care centers and sick leave among nursery; children.* Indoor Air, 2015. https://dx.doi.org/10.1111/ina.12202

169. Qian, H., et al., *Airflow and contaminant distribution in hospital wards with a displacement ventilation system*. 2004. 355-364.

170. Kane International. *What are safe levels of CO and CO2 in rooms?* 2018 [11/11/18]. Available from: https://www.kane.co.uk/knowledge-centre/what-are-safe-levels-of-co-and-co2-in-rooms

171. BRANZ. *Designing quality learning spaces: Ventilation and indoor air quality*. 2007; Available from: https://www.education.govt.nz/assets/Documents/Primary-Secondary/Property/School-property-design/Flexible-learning-spaces/VentilationIndoorAirQualityGuide.pdf

172. Chao, J. *Elevated Indoor Carbon Dioxide Impairs Decision-Making Performance*. News Center 2012; Available from: https://newscenter.lbl.gov/2012/10/17/elevated-indoor-carbon-dioxide-impairs-decision-making-performance/

173. Ministry of Education. *Designing quality learning spaces - Indoor air quality and thermal comfort*. 2017 [Version 1.0, September 2017]. Available from: https://education.govt.nz/assets/Documents/Primary-Secondary/Property/School-property-design/Flexible-learning-spaces/DQLSIndoorAirQualityThermalComfortV1.0.pdf

174. Hiura, T.S., et al., *Chemicals in diesel exhaust particles generate reactive oxygen radicals and induce apoptosis in macrophages.* Journal of Immunology, 1999. **163**(10): p. 5582-5591.

175. Liu, Q., et al., *Effect of exposure to ambient PM2.5 pollution on the risk of respiratory tract diseases: A meta-analysis of cohort studies.* Journal of Biomedical Research, 2017. **31**(2): p. 130-142. https://dx.doi.org/10.7555/JBR.31.20160071

176. Hertz-Picciotto, I., et al., *Early childhood lower respiratory illness and air pollution.* Environmental Health Perspectives, 2007. **115**(10): p. 1510-1518. https://dx.doi.org/10.1289/ehp.9617

177. Choo, C.P., et al., *Preschools' Indoor Air Quality and Respiratory Health Symptoms among Preschoolers in Selangor.* Procedia Environmental Sciences, 2015. **30**(Supplement C): p. 303-308. https://doi.org/10.1016/j.proenv.2015.10.054

178. Fuentes-Leonarte, V., J.M. Tenías, and F. Ballester, *Levels of pollutants in indoor air and respiratory health in preschool children: A systematic review.* Pediatric Pulmonology, 2009. **44**(3): p. 231-243. https://dx.doi.org/10.1002/ppul.20965

179. Rodriguez, C., et al., *The relationship between outdoor air quality and respiratory symptoms in young children.* International Journal of Environmental Health Research, 2007. **17**(5): p. 351-360. https://dx.doi.org/10.1080/09603120701628669

180. Moura, M., et al., *Air quality and acute respiratory disorders in children.* Revista de saúde pública, 2008. **42**(3): p. 503-511. https://doi.org/10.1590/S0034-89102008000300016

181. Pönkä, A., T. Poussa, and Laosmaa, M., *The Effect of Enhanced Hygiene Practices on Absences Due to Infectious Diseases among Children in Day Care Centers in Helsinki.* Infection, 2004. **32**(1): p. 2-7. https://dx.doi.org/10.1007/s15010-004-3036-x

182. Lemp, G.F., et al., *The relationship of staff to the incidence of diarrhea in day-care centers.* American Journal of Epidemiology, 1984. **120**(5): p. 750-758. https://dx.doi.org/10.1093/oxfordjournals.aje.a113943

183. Serra, M.E., *Prevention of respiratory infections at day care centers: Recommendations and systematic review of the evidence.* Archivos Argentinos de Pediatria, 2014. **12**(4): p. 323-331. https://dx.doi.org/10.5546/aap.2014.eng.323

184. Bean, B., et al., *Survival of influenza viruses on environmental surfaces.* Journal of Infectious Diseases, 1982. **146**(1): p. 47-51. https://dx.doi.org/10.1093/infdis/146.1.47

185. Carreiro-Martins, P., et al., *CO2 concentration in day care centres is related to wheezing in attending children.* European Journal of Pediatrics, 2014. **173**(8): p. 1041-1049. https://dx.doi.org/10.1007/s00431-014-2288-4

186. Business.gov.nl. *Childcare centre and playgroup accommodation requirements*. Business.gov.nl 2018 [9/12/18]. Available from: https://business.gov.nl/regulation/childcare-centre-playgroup-accommodation-requirements/

187. Clausen, G., et al., *Children's health and its association with indoor environments in Danish homes and daycare centres - methods.* Indoor Air, 2012. **22**(6): p. 467-475. https://dx.doi.org/10.1111/j.1600-0668.2012.00777.x

188. Clausen, G., et al. *Indoor Environment and Children's Health (IECH) - An ongoing epidemiological investigation on the association between indoor environmental factors in homes and kindergartens and children's health and wellbeing*. in *9th International Conference and Exhibition - Healthy Buildings 2009, HB 2009*. 2009. Available from: https://www.scopus.com/inward/record.uri?eid=2-s2.0-84872667683&partnerID=40&md5=5c8c41a3979d7447d1bd968d835dbdde

189. Nafstad, P. Jaakkola, J.J. K.; Skrondal, A.; Magnus, P., *Day care center characteristics and children's respiratory health.* Indoor Air, 2005. **15**(2): p. 69-75. https://dx.doi.org/10.1111/j.1600-0668.2004.00310.x

190. Wirsing, A., Brecht, W. and Passauer, I., *Interior climate and acute respiratory diseases in creches.* Kinderarztliche Praxis, 1985. **53**(5): p. 247-256.

191. Passauer, I. and Wirsing, A., *Indoor climatic conditions of the floor zone in child nurseries.* Arztliche Jugendkunde, 1989. **80**(5): p. 298-304.

192. Nurmi, T.S., Salminen, E.; Pönkä, A., *Infections and other illnesses of children in day-care centers in Helsinki II: The economic losses.* Infection, 1991. **19**(5): p. 331-335. https://dx.doi.org/10.1007/BF01645358

193. Yin, J.K., et al., *Estimates and determinants of economic impacts from influenza-like illnesses caused by respiratory viruses in Australian children attending childcare: A cohort study.* Influenza and other Respiratory Viruses, 2013. **7**(6): p. 1103-1112. https://dx.doi.org/10.1111/irv.12138

194. Söderström, M., *Diarrhoea risk study underlines the difficulties in carrying out research in day care centre settings.* Acta Paediatrica, International Journal of Paediatrics, 2016. **105**(1): p. 13-14. https://dx.doi.org/10.1111/apa.13239

195. Sedgwick, P., *Retrospective cohort studies: Advantages and disadvantages.* BMJ (Online), 2014. **348**. 10.1136/bmj.g1072

196. Petersen, N.J. and Bressler, G.K., *Design and modification of the day care environment.* Clinical Infectious Diseases, 1986. **8**(4): p. 618-621. https://dx.doi.org/10.1093/clinids/8.4.618

197. Chappell, P.R. *The Climate and Weather of Wellington*. 2014; 2nd:[Available from: http://docs.niwa.co.nz/library/public/NIWAsts65.pdf

198. Stats New Zealand. *2013 Census information by variable*. StatsNZ 2018; Available from: http://archive.stats.govt.nz/Census/2013-census/info-about-2013-census-data/information-by-variable/ethnicity.aspx

199. Kokiri Marae. *Kokiri Marae*. 2017; Available from: http://www.kokiri.org.nz/about/index.html

200. Ward, P., et al., *Paper/pencil versus online data collection: An exploratory study.* Journal of Leisure Research, 2014. **46**(1): p. 84-105. https://doi.org/10.1080/00222216.2014.11950314

201. Cobanoglu, C., Warde, B., and Moreo, P/J., *A comparison of mail, fax and web-based survey methods.* International Journal of Market Research, 2001. **43**(4): p. 441-452. https://doi.org/10.1177/147078530104300401

202. Meier, J.C., et al., *A new model for collection of clinical outcomes data in patients with chronic rhinosinusitis.* International Forum of Allergy and Rhinology, 2014. **4**(5): p. 411-415. https://dx.doi.org/10.1002/alr.21282

203. Kongsved, S.M., et al., *Response rate and completeness of questionnaires: A randomized study of internet versus paper-and-pencil versions.* Journal of Medical Internet Research, 2007. **9**(3). https://dx.doi.org/10.2196/jmir.9.3.e25

204. Marsh, J.D., et al., *Patients Respond Similarly to Paper and Electronic Versions of the WOMAC and SF-12 Following Total Joint Arthroplasty.* Journal of Arthroplasty, 2014. **29**(4): p. 670-673. https://dx.doi.org/10.1016/j.arth.2013.07.008

205. Hanscom, B., et al., *Computerized questionnaires and the quality of survey data.* Spine, 2002. **27**(16): p. 1797-1801. https://dx.doi.org/10.1097/00007632-200208150-00020

206. Touvier, M., et al., *Comparison between web-based and paper versions of a self-administered anthropometric questionnaire.* European Journal of Epidemiology, 2010. **25**(5): p. 287-296. https://dx.doi.org/10.1007/s10654-010-9433-9

207. Dominelli, A., *Web Surveys - Benefits and Considerations.* Clinical Research and Regulatory Affairs, 2003. **20**(4): p. 409-416. https://dx.doi.org/10.1081/CRP-120026122

208. Hunter, L., *Challenging the reported disadvantages of e-questionnaires and addressing methodological issues of online data collection.* Nurse Researcher, 2012. **20**(1): p. 11-20. https://doi.org/10.7748/nr2012.09.20.1.11.c9303

209. Klein, J., *Issues surrounding the use of the internet for data collection.* American Journal of Occupational Therapy, 2002. **56**(3): p. 340-343. https://doi.org/10.5014/ajot.56.3.340

210. Keusch, F., *Why do people participate in Web surveys? Applying survey participation theory to Internet survey data collection.* Management Review Quarterly, 2015. **65**(3): p. 183-216. https://dx.doi.org/10.1007/s11301-014-0111-y

211. Alessi, E.J. and Martin, L.I,. *Conducting an internet-based Survey: Benefits, pitfalls, and lessons learned.* Social Work Research, 2010. **34**(2): p. 122-128. https://doi.org/10.1093/swr/34.2.122

212. Pugh, C.A., et al., *Validity of internet-based longitudinal study data: The elephant in the virtual room.* Journal of Medical Internet Research, 2015. **17**(4): p. e96. https://dx.doi.org/10.2196/jmir.3530

213. Singer, E., *Toward a benefit-cost theory of survey participation: Evidence, further tests, and implications.* Journal of Official Statistics, 2011. **27**(2): p. 379-392.

214. Stats New Zealand. *Ethnicity*. Stats NZ 2018 [20/10/18]. Available from: http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/ethnicity/definition.aspx

215. Ministry of Health. *Presenting ethnicity - comparing prioritised ethnicity and total response ethnicity in descriptive analyses of NZ Health Monitor surveys*. 2008; Available from: http://www.moh.govt.nz/notebook/nbbooks.nsf/0/4b1c9119d4e5ea78cc257488000d9324/$FILE/presenting-ethnicity-2008.pdf

216. Shorter, C., et al., *Indoor visible mold and mold odor are associated with new-onset childhood wheeze in a dose-dependent manner.* Indoor Air, 2018. **28**(1): p. 6-15. https://dx.doi.org/10.1111/ina.12413

217. Best Practice Advocacy Centre New Zealand Limited. *Diagnosing and managing asthma in children*. BPAC NZ 2012 [13/1/19]. Available from: https://bpac.org.nz/bpj/2012/february/asthma.aspx

218. Ministry of Health. *Immunise against chickenpox - Protect your child*. 2017; Available from: https://www.healthed.govt.nz/system/files/resource-files/HE2519_Immunise_against_chickenpox.pdf

219. Dooney, L. *Early childhood teachers are stressed and bullied at work, according to new survey*. Stuff national 2016 [22/11/18]. Available from: https://www.stuff.co.nz/national/education/80406271/early-childhood-teachers-are-stressed-and-bullied-at-work-according-to-new-survey

220. Teachers Advocacy Group. *Teachers Advocacy Group* Facebook 2018 [24/11/18]. Available from: https://www.facebook.com/groups/1797635297122360/

221. *World Population Review*. 2019 [24/2/19]. Available from: http://worldpopulationreview.com/world-cities/helsinki-population/

222. Prussin, A.J., II, et al., *Survival of the enveloped virus Phi6 in droplets as a function of relative humidity, absolute humidity, and temperature.* Applied and Environmental Microbiology, 2018. **84**(12). https://dx.doi.org/10.1128/AEM.00551-18

223. Deyle, E.R., et al., *Global environmental drivers of influenza.* Proceedings of the National Academy of Sciences of the United States of America, 2016. **113**(46): p. 13081-13086. 10.1073/pnas.1607747113

224. Shaman, J. and Kohn, M., *Absolute humidity modulates influenza survival, transmission, and seasonality.* Proceedings of the National Academy of Sciences of the United States of America, 2009. **106**(9): p. 3243-3248. 10.1073/pnas.0806852106

225. Ministry of Housing and Urban Development. *Healthy homes standards*. 2019 [25/2/19]. Available from: https://www.hud.govt.nz/residential-housing/healthy-rental-homes/healthy-homes-standards/

226. World Health Organisation. *WHO Housing and health guidelines*. 2018 [24/2/19]. Available from: https://apps.who.int/iris/bitstream/handle/10665/276001/9789241550376-eng.pdf?ua=1

227. Telfar Barnard, L., Howden-Chapman, P., Clarke, M., Ludolph, R. *Web Annex B: Report of the systematic review on the effect of indoor cold on health*. WHO Housing and health guidelines, 2018.Available from: https://apps.who.int/iris/bitstream/handle/10665/275839/WHO-CED-PHE-18.03-eng.pdf

228. Fisk, W.J., Lei-Gomez, Q. and Mendell, M.J., *Meta-analyses of the associations of respiratory health effects with dampness and mold in homes.* Indoor Air, 2007. **17**(4): p. 284-296. https://doi.org/10.1111/j.1600-0668.2007.00475.x

229. Ministry of Education. *He taonga te tamaiti - every child a taonga: Strategic plan for early learning 2019-29*. 2018; Available from: https://conversation.education.govt.nz/assets/ELSP/Early-Learning-Strategic-10-Year-Plan.pdf

230. Reynolds, D.J.J. and Stiles, W.B., *Online data collection for psychotherapy process research.* Cyberpsychology and Behavior, 2007. **10**(1): p. 92-99. https://dx.doi.org/10.1089/cpb.2006.9987

231. Ministry of Education. *PF12 Heating, lighting, noise, and ventilation*. Licensing criteria for centre-based ECE services 2018 [25/11/18]. Available from: https://www.education.govt.nz/early-childhood/licensing-and-regulations/the-regulatory-framework-for-ece/licensing-criteria/centre-based-ece-services/premises-and-facilities/general/pf12-heating-lighting-noise-and-ventilation/

232. Carroll-Lind, J. and Angus, J., *Through their lens: An inquiry into non-parental education and care of infants and toddlers*. 2011; Available from: http://www.occ.org.nz/assets/Uploads/Reports/Education/Through-their-lens.pdf

Appendix 1: Extract from Regional Public Health Submission – Draft Criteria for Licensing of ECE Services

---

Regional Public Health
Better Health For The Greater Wellington Region

Regional Public Health
Hutt Valley District Health Board
Private Bag 31-907
Lower Hutt
New Zealand

4 October 2006

Submitted by email to: ece.reviews@minedu.govt.nz

Submission on the
Draft Criteria for the Licensing or Certification of ECE Services

Thank you for the opportunity to provide a written submission on the Draft Criteria for the Licensing or Certification of ECE Services.

The submission is from Regional Public Health (RPH), which provides public health services for the three District Health Boards in the Wellington region.

Regional Public Health is willing to provide further advice or clarification on any of the points raised in this submission. The contact point for this submission is:

Mike Bedford
Early Childhood Centre Wellbeing Team
Regional Public Health
Hutt Valley District Health Board
Private Bag 31-907
Lower Hutt
Telephone: 04 570 9002
Email: mike.bedford@huttvalleydhb.org.nz

1. Regional Public Health

[General detail about Regional Public Health as an organisation deleted]

The Early Childhood Centre Wellbeing Team

The Early Childhood Centre Wellbeing programme for the Wellington Region was developed in 1996, and is unique in New Zealand in that it:

1. Employs a specialist team for Childhood Centre Wellbeing.
   Uses a *Te Whāriki* -based approach linked to Health Promotion strategy.

The key principles of the programme are:

- Recognition that early childhood teachers are motivated to achieve the best outcomes for children, and usually need help with health issues rather than regulatory enforcement.

- Recognition that inspection is not always an appropriate tool to achieve public health gains, and can place a barrier between health workers and early childhood teachers and managers. This barrier is made worse when health workers have little knowledge of the early childhood education sector.

- Understanding that specialist knowledge of the early childhood education sector is essential to effective health work in those settings. Health workers must have an understanding of the organisational, cultural and philosophical diversity of the sector, child development needs, knowledge of the curriculum, and of the day-to-day pressures of the environment for children, teachers and parents.

- The recognition of the *Te Whāriki* objective that children should be "competent and confident learners, healthy in mind, body and spirit". In practice this means the adoption of risk assessment practices that weigh potential harm against children's developmental needs for physical, biological, communicative, cognitive, and social challenge.

- The use of *Te Whāriki* as a platform for Health Promotion. *Te Whāriki* meshes perfectly with the Ottawa Charter for Health Promotion as a holistic and integrated model. *Te Whāriki* makes it clear that early childhood centre health issues should not be addressed in isolation from belonging, exploration relationships etc that are the *Te Whāriki* weave.

- The use of local workshops to inform best practice and design. From 1996 all advisory visits to ECCs (on a 3 yearly cycle) are preceded by small group workshops. At these workshops a fundamental principle is 'everything is challengeable' and debate around issues is welcomed. This is proving to be an excellent system for informing the Public Health programme, and for working through practical solutions to many issues.

Strategic Summary - Health is Everyone's Business

Earlier this year, the Public Health Advisory Committee submitted a report to the Minister of Health on the implications of a changing context for public health in New Zealand. The report is entitled – 'Health is Everyone's Business'.[6] The Foreword states:

Improving New Zealanders' health and wellbeing requires more than the provision of health services. Good health and the prevention of illness, and dealing well with disability, is a significant outcome of the settings in which people live their lives. Diet, housing, safe neighbourhoods, clean air and water, access to transport, education and employment are just some of the factors determining overall patterns of health and well-being.

Most of the central and local government agencies whose actions affect these settings lie outside the health sector. Collaborative action, a 'whole of government' response, is required if health is to be improved, illness prevented, and disability well addressed.

The success of a 'whole of government' approach depends on other stakeholders accepting their share of responsibility for realising health improvements. Public health units are encouraged to identify the wider determinants of health and focus attention on the influencing factors outside the health sector. This approach involves taking an 'upstream' approach which proactively aims to prevent ill-health and improve the health of the population.

2. General Comments

The overall model of regulations accompanied by the criteria structure is good. It is usually helpful to have details of design or practice at a level lower than regulations, to allow for easier changes. The 'example' information is likely to be very helpful for ECE services.

We support the proposed Guidance documents that will underlie the *Criteria* as these will provide the opportunity for agencies and centres to share details of innovative and practical design, practice and management that will assist with compliance with the *Criteria*.

We would like the opportunity to contribute to the development of these Guidelines.

Licensing Comments

The licensing and certification processes for Home-based Services and Playgroups have raised some concern among Public Health Units. As Home-based Services are attended by less than 5 children each, and Playgroups are generally attended by smaller numbers

---

[6] **Public Health Advisory Committee**, July 2006

of children than licensed centres, and have a ratio better than 1 parent: 2 children, these services have not been seen as a priority for population health input. Exceptions to this have been unlicensed Pasifika Playgroups.

The wording in the 1998 Regulations allows the Ministry of Education to 'request a health report' but this report need can be met by consultation between Ministry of Education and Public Health Unit staff. The optional status of licensing and certification for these groups may reduce the impact of these processes.

3. Licensing Criteria for Centre-based ECE Services

2.2 - 2.5 General

Very good – points to a comprehensive environment rather than a play environment, and supports practical supervision.

2.6 New Zealand Standards

This criterion needs to be modified (from Regulation level) to provide to the Ministry of Education discretionary powers to waive or modify the requirements of NZ Standards.

This need arises because:

a) Standards may not necessarily be written in a way that recognizes the special nature of an early childhood education environment.

b) Standards are often written on the assumption that they will be voluntary, and hence have less legal rigor applied than would normally be the case for a legal requirement.

2.8 Glass

Needs addition of the use of safety film as an option.

2.9 Storage Space

Very good – failure to provide adequate storage space is a common design fault.

2.11 Staff Space

Excellent! This is very necessary but often overlooked. A good working environment for staff should be a basic consideration in the planning of a Centre.

2.12 Sick Child Space

Needs more clarification. 'Isolation' as such is rarely necessary to protect the health of others – it is more about giving an unwell child a quieter space. From this point of view provision of a bed for a sick child in the office space is often the most practical option for everyone.

2.14 Art Sink

The most important hygiene division here is not art / hand washing but art / general cleaning. It is more important to prevent cleaning buckets being emptied down the art sink, as paint brushes may go into children's mouths. The art materials are not a hygiene hazard.

Agreed though that a dedicated art sink is needed.

2.16 Heating and Ventilation

More specific criteria for ventilation is required - this is a significant health issue. The minimum room temperature should be increased to 18°C, in line with WHO recommendations for housing.

2.17 Outdoor Space

Not unduly restricted by resource consent conditions with regards to …". Very good and much needed.

2.18 and 2.19 Hand Washing Facilities

The 1:15 ratio needs to change. For almost all ECE facilities, the 1:15 ratio for hand washing facilities is inadequate and inappropriate, given the need to both maintain good hygiene and educate children in care of their bodies. The ratio bears no relationship to ECE needs.

"Toilet and hand washing … adequately separated from … play or food preparation". Hand washing facilities in play areas are a major hygiene advantage, and need to be encouraged rather than discouraged. This clause could also suggest a greater separation of toilet facilities than is necessary. Gastrointestinal infections are almost never transmitted through the air from toilet facilities. From a hygiene perspective toilet facilities need only be separated from other areas in a way that designates the areas, e.g. a doorway, (not a door) although aesthetic and cultural issues may indicate greater separation.

Soap: Bar soap is relatively unhygienic and should not be used in early childhood services. Liquid or foam soap should be used.

Hand drying facilities are just as important as hand washing facilities. Hand drying should be by means of re-usable cloths that are only used once before laundering, or paper towels. Hot air dryers and roller towels are not appropriate in early childhood services.

Liquid or foam soap and hygienic hand drying should also be used with adult hand washing facilities.

2.20 Toilet privacy

Very good – children's need for privacy is sometimes ignored.

2.23 Nappy change

Very good. Minimising of adult back strain should also be a design criterion.

2.24 Bathing

Please do not recommend or suggest shubs or full size baths for bathing – they increase back strain and back injury. The best arrangements are waist-height tubs for babies and hand-held showers for older children.

2.25 Kitchen Facilities

Kitchens need to have hand washing facilities in addition to the kitchen sink. While it is common for public health advice to specify a separate wash hand basin, this may be impractical if the basin is installed simply to meet a regulation, for example, tucked into a corner of the kitchen where it won't be used. In order to achieve an actual hygiene gain, we recommend the following:

"A wash hand basin should be installed in a place in the kitchen which will be convenient and practical for use during food preparation. Alternatively, a double sink unit may be used, with one sink dedicated as a hand washing sink. The hand washing facility should be supplied with liquid soap and paper towels."

2.27 – 2.31 Sleep facilities

We are concerned that the 1 sleeping space to 2 children ratio is less than adequate. This ratio has disadvantages for children's health.

- The ratio assumes that no more than half of the children will need rest at any given time.
- Because the cots are not dedicated to one child each, it is very tempting for staff to use cots for more than one child without changing the bedding. (This has been observed by our staff.)

- The ratio encourages the use of very small rooms, increasing the likelihood of respiratory infection transfer in a small air space.

This is consistent with the comments on p92 (Topics for Discussion). We see no reason why New Zealand should adopt a lesser standard. The economics of sleep room provision must be weighed against the cost of infections.

Ventilation is also very important in sleep rooms. We recommend that sleep rooms be required to have ventilation which is:

- Flow through, i.e. has an inlet and an outlet
- Reasonably able to be used in all weather conditions.

3.3 Evacuation

Extra criteria needed here – emergency egress should ensure that children are not trapped in an outside area that could become dangerous in the event of a fire. This is important for smaller back garden areas.

There is also a need for an evacuation destination which is a suitable building, as evacuation may mean an inability to re-enter the building in the short term, and may happen in bad weather.

3.5 Emergency supplies

We recommend this information be tailored to the needs of ECE Services and also be available on the MOE web site.

3.8 Cots and beds

Good, but needs better guidelines on ventilation (see 2.16).

3.10 Safety hazards

The OSH approach cannot be applied without modification in ECE environments, specifically:

"All practical steps are taken to eliminate, isolate or minimize, hazards to the safety of children."

It is essential that children develop skill in relation to their own bodies and environmental hazards. The retention of some features that present a risk of minor injury is necessary for this aspect of child development. Better wording might be:

"All practical steps are taken to eliminate, isolate or minimize significant hazards to the safety of children or adults, while allowing for developmentally appropriate levels of minor risk."

Serious harm might further be defined as any level of injury requiring urgent medical attention or hospitalization. In working through OSH issues on this, reference could reasonably be made to Labour Dept interpretation of the HSE for sporting activities.

3.11 Food Quality and Nutrition

this clause could be clarified by adding after "…nutritional needs of the children", "consistent with the Ministry of Health *Food and Nutrition Guidelines for Healthy Infants, Toddlers and Children*".

We also recommend replacing "encourages and promotes health eating guidelines" with "encourages and promotes use of The Food and Nutrition Guidelines".

3.12 Food Hygiene

Food brought from home to be shared e.g. birthday cakes, can be a significant hygiene hazard. There is no control over domestic hygiene, and home environments are more likely to be an infection risk when they house pre-school children. Food brought from home to be shared should be:

- Not readily-perishable
- Prepared with minimal handling

For example, fruit should be whole, for washing and chopping at the Centre. Birthday cakes should be iced or decorated at the Centre, not at home.

3.15 Bottle Feeding of Infants

We are concerned that six months is too young for the lower limit on children being bottle fed without being held. Children over six months are still likely to adopt a position that is unsafe for them while holding a bottle. We recommend a minimum age of 12 months before a child is given a bottle without being held.

3.18 Water delivery temperature

"No higher, (but near to), 40°C." This needs to be re-worded. 40°C exceeds comfort level for many children. About 35-38°C is comfortable. A better guideline might be:

"The temperature… must be warm (between 35°C and 40°C) and must be comfortable for all children at the Centre to use."

3.19 Water storage temperature

Technical correction. Cryptosporidium is not a bacterium and doesn't grow in water. It is not a significant risk in relation to hot water supplies. The microbiological rationale relates to Legionella.

3.20 Noise

Very good.

3.26 Infectious Diseases Reference for Action

Refer to comments on Appendix 2.

3.27 Isolation

"Potentially contagious" is not helpful wording here. For example, impetigo is potentially contagious, but if the lesions can be covered is not a reason to isolate or exclude a child.

Isolation to *prevent disease spread* is appropriate where a child has symptoms that make transmission risk likely, e.g. vomiting, coughing, sneezing, or conjunctivitis.

3.30 Medicines

Very good. The reference to category (ii) needs to be qualified by the need for a child to be asymptomatic and not infectious. Parents sometimes think that if a child is receiving treatment they can automatically return to the Centre, e.g. with antibiotic treatment for conjunctivitis. This is not the case and there would be few conditions for which it is reasonable for a centre to be providing category (ii) medication.

Appendix 1

As First Aid list guidelines may be amended over a time frame not linked to review of the Criteria, it would be better to have a pointer to some more easily updated reference, such as a website, with a printed version available.

Appendix 2

As for Appendix 1, it may be better also to have this reference table on the MOE web site, as well as a printed version. The format of this table is very good but it needs to be revised and updated. It should include more information on diarrhoea and enteric diseases, conjunctivitis, scabies, nits, slapped cheek and hand foot and mouth diseases. These conditions occur commonly in centers and generate highest level of calls to Public Health Units. In addition, for enteric diseases more emphasis needs to be placed on toy hygiene, hand hygiene, and nappy changing techniques

Glossary

"Potable" unless given a legislative definition, means 'fit to drink'. This covers taste as well as microbiological and chemical quality. It may best to use the definition in the Drinking Water Standards NZ 2005.

"Medicine" – the definition should not include "promotes recovery" as this would include good nutrition, e.g. fruit and vegetables, and water. The Medicines Act 1981 uses the definition "for a therapeutic purpose".

"Non-porous material" also includes substances that absorb water.

Appendix 2: Regional Public Health Comments on the 2007 Ministry of Education 'Design and Build' Project Draft Plans

---

Communication sent by email
Hutt Valley DHB to Ministry of Education
November 2007

Thank you for the opportunity to contribute to the Build and Design Project. Overall, we were very impressed with the careful attention to detail and the thoughtful consideration and provision of a range of different areas for children, families and teachers.

Overall scheme:

We strongly support many of the features and concepts you have incorporated into the Build and Design Project. These include:

Whanau area – This is a wonderful opportunity to ensure that family/whanau also feel a sense of belonging within the centre. Whanau areas are a welcoming place where families have opportunities to meet each other or can simply take time to relax before going to work. They also provide perfect opportunities for parents and families to watch their children playing.

Teacher space – Allocating a designated and relaxed environment for teachers shows consideration for their health and well-being. Placing a kitchenette is also a great idea.

Kitchen – The placement of the kitchen guides people towards the concept of a home environment, with the kitchen as the hub. The kitchen placement offers great opportunities for teaching and learning. It also offers very good supervision. A double sink works really well.

Indoor/outdoor flow – wonderful opportunities for child initiated play and exploration with easy flow access to all areas. Multiple access to outside areas relieves thoroughfares and reduces the disruption of activities.

Separate outdoor areas – Shows consideration for all age groups as they are allocated individual space according to age and ability.

Bathing areas – The bathing needs of babies and older children have been thoughtfully considered. Baby bathing is conveniently located on a well-spaced bench. The wet floor area in the adult bathroom saves on space and is far more convenient and safer to use than a shub design.

Sleep room – The placement of the sleep rooms close to the activity area in the infant and toddler room allows for easy access and monitoring.

Generic Suggestions:

Reduce the core module to increase the activity module – The core module could be reduced by 1m by reducing the size of the office and the entry by a nominal ½ m each. The result would be a 1m reduction in the whanau area.

This would increase the activity area to approximately to **3.47m²** per child. The original layout was approximately just under 3.1m² which was less than the 3.3m² minimum space requirements for Victoria for example.

We would suggest using 1 ½ doors in the entrance area.

The divider between the whanau area and the main area should allow for full vision into the area.

Locating the kitchen next to the whanau area is the preferred option as this allows for better supervision and gives a sense of the kitchen as a hub.

Locating all of the utilities on one side of the building is more convenient. This removes the obstruction to view for the outside play area and makes it easier to adjust plans for the mixed age group, over 2 and under 2.

To mirror orientation of core module and still retain visibility from the whanau area the entry should be flush with the kitchen wall. The use of an 800mm high divider between the dining/wet activity area and whanau area gives the flexibility needed.

Rather than using a counter which does not really promote a family/whanau concept we would suggest keeping the slide window but removing the counter. A sign in desk could still be used.

Using gates with windows where possible rather than doors can also help to create a sense of connection.

In some locations it could work well to offset the doors by moving doors from a central location to the side.

Placing a hand-washing trough outside of the kitchen would be advantageous.

Windows placed at both infant height and adult height has been included in various locations.

[Additional text deleted as not applicable to this thesis]

Appendix 3: New Zealand Schedule of Notifiable Diseases

Source: https://www.health.govt.nz/our-work/diseases-and-conditions/notifiable-diseases

Accessed 16/2/19

---

4 January 2017

List of diseases notifiable by health practitioners and laboratories to the Medical Officer of Health

Diseases Notifiable in New Zealand (include suspected cases)*

Notifiable Infectious Diseases Under the Health Act 1956

Section A – Infectious Diseases Notifiable to a Medical Officer of Health and Local Authority

Acute gastroenteritis **
Campylobacteriosis
Cholera
Cryptosporidiosis
Giardiasis
Hepatitis A
Legionellosis
Listeriosis
Meningoencephalitis – primary amoebic
Salmonellosis
Shigellosis
Typhoid and paratyphoid fever
Yersiniosis

Section B – Infectious Diseases Notifiable to Medical Officer of Health

Anthrax
Arboviral diseases
Brucellosis
Creutzfeldt-Jakob disease (CJD) and other spongiform encephalopathies
Cronobacter species
Diphtheria
Haemophilus influenzae b
Hepatitis B
Hepatitis C
Hepatitis (viral) not otherwise specified
Hydatid disease
Highly Pathogenic Avian Influenza (including HPAI subtype H5N1)
Invasive pneumococcal disease
Leprosy
Leptospirosis
Malaria
Measles
Middle East Respiratory Syndrome (MERS)
Mumps
Neisseria meningitidis invasive disease
Non-seasonal influenza (capable of being transmitted between human beings)
Pertussis
Plague
Poliomyelitis
Q fever
Rabies and other lyssaviruses
Rheumatic fever
Rickettsial diseases
Rubella
Severe Acute Respiratory Syndrome (SARS)
Tetanus
Tuberculosis (all forms)
Verotoxin-producing or Shiga toxin-producing *Escherichia coli*
Yellow fever
Viral haemorrhagic fevers

Section C- Infectious Diseases Notifiable to Medical Officer of Healt without Identifying Information of Patient or Deceased Person

Acquired Immunodeficiency Syndrome (AIDS)
Gonorrhoeal infection
Human Immunodeficiency Virus (HIV) infection
Syphilis

Diseases Notifiable to Medical Officer of Health (Other than Notifiable Infectious Diseases)

Notifiable to the Medical Officer of Health

Cysticercosis
Decompression sickness
Lead absorption equal to or in excess of 0.48µ mol/l (10µg/dl)***
Poisoning arising from chemical contamination of the environment
Taeniasis
Trichinosis

---

* During times of increased incidence health practitioners may be requested to report, with informed consent, to their local medical officer of health cases of communicable diseases not on this list.

** Not every case of acute gastroenteritis is necessarily notifiable, only those where there is a suspected common source or from a person in a high risk category (for example, a food handler, an early childhood service worker) or single cases of chemical, bacterial, or toxic food poisoning such as botulism, toxic shellfish poisoning (any type) and disease caused by verotoxin or Shiga toxin- producing *Escherichia coli*.

*** Where occupational exposure is suspected, please also notify the agency responsible for workplace health and safety through the notifiable occupational diseases system.

Appendix 4: Examples of Climate Variations in Wellington Regional Suburbs

Figure 53: Concurrent forecasts for a five-day spring period in October 2018, illustrating differences in the microclimates of Wellington and the Hutt Valley Suburbs.

Note the 13.5ºC point-in-time difference in morning temperatures (left hand side of panels).

Source: www.metservice.com/towns-cities/wellington

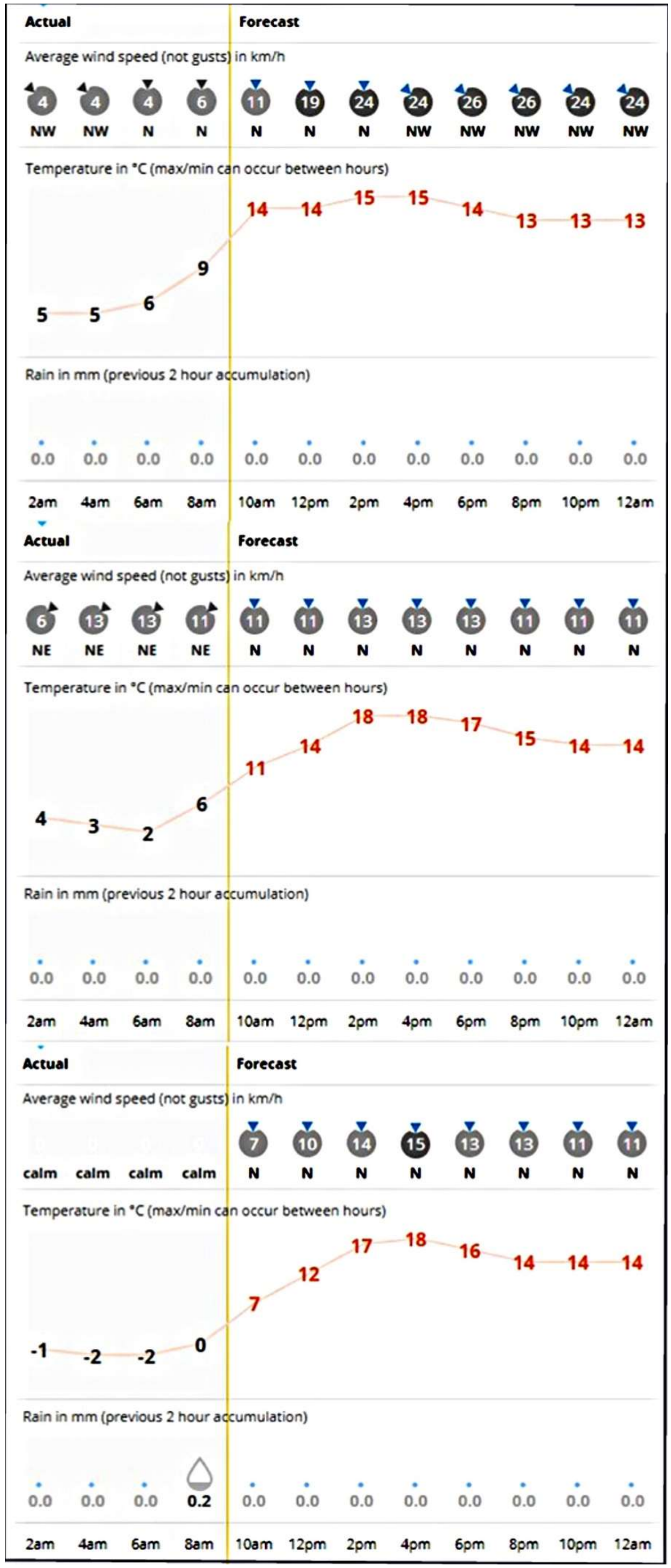


Figure 54: One-day diurnal variations in temperature and wind speed for Wellington City (top), Lower Hutt (centre) and Wainuiomata (bottom), October 2018.

In this example the Wellington City diurnal extremes are within a much narrower temperature band (6 to15°C) than Lower Hutt (2 to 18°C) or Wainuiomata (-2 to 18°C). On the same day Wellington City actual and forecasted average hourly wind speeds ranged from 4 km/h to 26 km/h, while in Lower Hutt it was 6 km/h to 13 km/h, and in Wainuiomata from calm to 15 km/h.

Appendix 5: Online data entry literature review

A literature review was conducted to look for experiences with similar research methods, and for information about best practice in online data collection.

The terms required in the literature review were very common, including “online”, “website” “questionnaire”, “research” and “longitudinal”. For this reason the literature review began with a series of phrase terms to try to find a manageable number of titles. From the initial search a daisy-chain method was used to find other relevant references from bibliographies (refer to Table 34).

Table 36: Initial search phrases and results from Scopus – title and abstract search

Search phrase	Titles	Year Limit
"website data collection"	8	
"continuous website data"	0	
"online data collection"	191	2006
“continuous online data collection”	0	
“continuous online data”	3	
“repeated online data collection”	0	
“long term online data”	0	
“online research”	548	2010
“online questionnaires”	215	2010
“longitudinal online”	28	
Total	**993**	

From the initial 993 titles and subsequent snowball searches 33 articles were found relevant at abstract level, with 27 available for full text review. Very few articles described a longitudinal study with multi-session data entry by participants not recruited online. Two articles were found relating to continuous longitudinal studies, one being a survey of Labrador Retriever owners called the Dogslife Study [212], and the other being a psychotherapy voluntary longitudinal study [230]. All other studies that were described as ‘longitudinal’ were a series of two or three questionnaires at set time intervals, for example one year or two years after an initial event such as surgery. It was however difficult to determine whether continuous online data entry was used in any given study from the phrase search, as that level of detail was only evident when reading the full text. None of the methodological articles referred to continuous online data entry. Much of what has been written concerns the ethics of online recruitment and a researcher-respondent relationship that is wholly online.

The longitudinal data provided by parents in the ECEE study was categorical and quantitative, so many of the concerns discussed in papers about online research, including subjectivity and personal image, had minimal application to this study.

Experiences with continuous online data collection

The Dogslife Study [212] was similar to the ECEE study illness data collection method in that adults were reporting data for a subject who could not themselves report, and were reporting over an extended period of time using an online system. The participants had a direct interest and care for the main subjects of the study, and were themselves secondary subjects of the study. Owners were contacted and then sent a form to sign to request their dogs' veterinary records. A greater proportion of records was obtained from owners contacted by phone than those contacted by email.

The authors stated that "… the design of Dogslife as an Internet-based project should have minimized recall decay as owners may enter new information at their convenience, and were not limited to reporting when an interviewer visits or the next questionnaire comes through the post. However, the interval between Dogslife data entries peaked at 37 days for dogs under one year and 90 days for dogs aged over a year. Owners were returning when they received reminder emails, not when there was a recent incident to report." They concluded that automated communication does not remove the need for personal interactions. The authors commented that bias from loss to follow-up is a well-recognized problem in longitudinal studies, and that investigators need to design their questionnaire to minimise fatigue in participants.

In the Dogslife study validation of questions was challenging, due to the complexity of the information required. For example, keeping the questionnaire relatively brief was incompatible with the unexpected complexity of canine diets. The authors also noted difficulty with respondent's ability to reliably take measurements, for example of the dog's weight.

The authors said that ideally, each parameter would be validated against a reliable external data source, e.g. the records of clinic visits. For certain parameters, such as illnesses that do not result in a visit to health professionals, external sources may not exist, so the data could not be directly validated. This was the case for the ECEE study, as the study was specifically aiming at recording illness not recorded elsewhere. As for the Dogslife study, answers would have to be accepted as respondent observations.

The study by Reynolds et al [230] involved participants drawn from a psychology department clinic, a student counselling centre, and community agencies visited an online site to report on each of their sessions. A weekly email with a link to a website login screen was sent to all participants that had not completed the forms for that week. When they logged in, participants were presented with the status screen, which had links for the current and the immediately prior week. They could report a week's session as having been missed or provide ratings of their session. The authors reported that some clients and therapists visited the online database on a regular basis, but recruitment and participation was problematic.

On the positive side the study results were seen by Reynolds et al to offer encouragement for researchers seeking to collect longitudinal data online. Therapists and clients were able to register at a secure online site and complete these forms successfully from several internet access locations. The response rate was lower than they hoped however. They commented that this was not surprising for volunteer participants in applied mental health settings.

Online data entry advantages

The overall assessment of online data collection versus other methods was positive. Commonly reported advantages included better participant engagement, improved response times [200] and better quality of data, with less time and cost required for data collection. [104, 201].

Improved participant engagement

Participant engagement as good or better than paper-based surveys [202-205]. Touvier et al commented that the web-based version of their survey was preferred by 92.2% of 128 users who completed the ‘‘satisfaction questionnaire’’. Although the time needed to fill out the questionnaires was comparable for the paper-based and online versions, the web-based version was considered more satisfactory than the paper version. Among them, 18.8% declared that it helped them to detect a mistake and correct it. About 94.5% of the participants felt that the web-based interface was user-friendly, while 88.3% appreciated the ‘‘mid-questionnaire support message’’. [206] In a post-operative survey by Meier et al the response rate increased from 68% to 78.8% three months after surgery. [202]

Data quality

Traditional paper-based questionnaires may generate data entry mistakes along with missing, inconsistent or abnormal data [104, 206]. Kongsved et al stated that for the internet version of their study, 97.8% filled in a complete questionnaire without missing data, while 63.4% filled in a complete questionnaire for the paper-and-pencil version (risk difference 34.5%, $P < .001$).[203]. Web surveys allow for automated coding of survey results. This feature virtually eliminates the expenditure of time spent in processing completed surveys. It also significantly reduces the possibility of manual errors in the coding and data entry of survey responses. [205, 207].

Appendix 6: Childcare centre and staff introduction

ECEE

Early Childhood Education Environments Study

He Kainga Oranga – Housing and Health, University of Otago, Wellington

Supported by BRANZ

The ECEE study is the first New Zealand study to look at how indoor environments in ECE affect children's health.

Criteria for Licensing contains minimum standards for temperature and space, but we don't have any measures of actual space and temperatures. We're not expecting any results that don't comply, but we know there will be variations. We also don't have any measures of indoor air quality.

Children attending ECE are exposed to a range of infections, with high rates of respiratory infections, gastrointestinal infections and glue ear, and sometimes outbreaks occur that can affect whole ECE services. Some of this is just a matter of mixing with others and encountering some illnesses for the first time, or the hygiene challenges with very young children. The spaces children are in may matter too though, and that's the focus of this study.

There are still things we don't know about how often children attending ECE get sick, why and what with, and how often parents have to take time off work.

How the study works

The study puts together two sets of information:

- What are the temperatures, humidity levels, and spaces per person in ECE?
- How often do children and teachers get sick, and what with what, and how much time do parent need off work?

From winter to spring 2017 we'll be measuring temperatures and humidity in ECE Services. We may also take some other measurements, such as carbon dioxide levels.

We'll be enrolling children and teachers from the Centres, to collect information on how often they get sick and what with. Collecting information about a child or teacher's illness will be triggered by them being off sick.

Confidentiality

When we publish information from the study, we won't be identifying any individual ECE Service or any people. We will match child and teacher health to the days they experience different temperatures, humidity or space per person. To be able to measure exposures this way we'll need to get attendance information each week – who was away, and who was away sick.

The website used by parents and teachers to enter illness data will be confidential. Enrolment details will be kept separate and secure, not on the website.

Enrolments

We aim to enrol about 600 children, and any teachers or support staff willing to provide information about their own illnesses and absence from work. To do this we need to have about 25 ECE Services enrolled. Within the constraints of full day and only over twos, we need a representative variety of centres in our study so that we can see how ranges of conditions might have an effect.

Value to ECE Centres

Besides providing information on childhood illness, we expect the results of this study to assist BRANZ to develop guidelines for ECE environmental design, including ventilation and heating.

About the study team

The study is part of a PhD undertaken by Mike Bedford. Mike has a Master of Public Health and has worked in early childhood education health since 1992, much of that time with Wellington Regional Public Health. Now with the He Kainga Oranga – Housing and Health Team at the University of Otago, Wellington. He's keen to see more New Zealand research on environments for children.

The following researchers from the University of Otago will have access to the data collected…

Mike Bedford
Dr Lucy Telfar-Barnard
Dr Julie Bennett
Dr Caroline Shorter
Prof. Julian Crane

Two or three additional He Kainga Oranga team members may assist with phone calls.

Who to contact

If you'd like to know more about the study phone or text Mike on [phone number] or email him at [email address]

For Maori health support please contact Mike, who will direct you to a Maori health support person.

The lead PhD supervisor for this research is Lucy Telfar-Barnard. Lucy can be contacted at [phone number]

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone:	[phone number]	Fax:	[phone number]
Email:	[email address]		

You can also contact the health and disability ethics committee (HDEC) that approved this study on:

Phone:	[phone number]
Email:	[email address]

Appendix 7: Childcare centre enrolment form

Figure 55: Childcare centre consent form

ECEE

UNIVERSITY of OTAGO NEW ZEALAND

Early Childhood Education Environments Study

ECE Centre Consent Form

I've read the information about this study and I agree to the participation of

____

Name of ECE Service

in the ECEE study. I am authorised to give this permission. I understand that measurements will be taken temperature, humidity, CO_2, air volume and area in the activity and sleep spaces. These measurements will take place in 2016 and 2017.

I agree to have parents of children attending this ECE Service enrol their children in the study if they choose to, and for staff who wish to participate to do so. I understand that the identity of this ECE Centre and the participants in the study will be kept private to the study team. When information from the study is made available to others no personal details will be included. Published information from this study will not name any participants or individual ECE Services.

Name of person authorising enrolment ____________________________

Job title ____

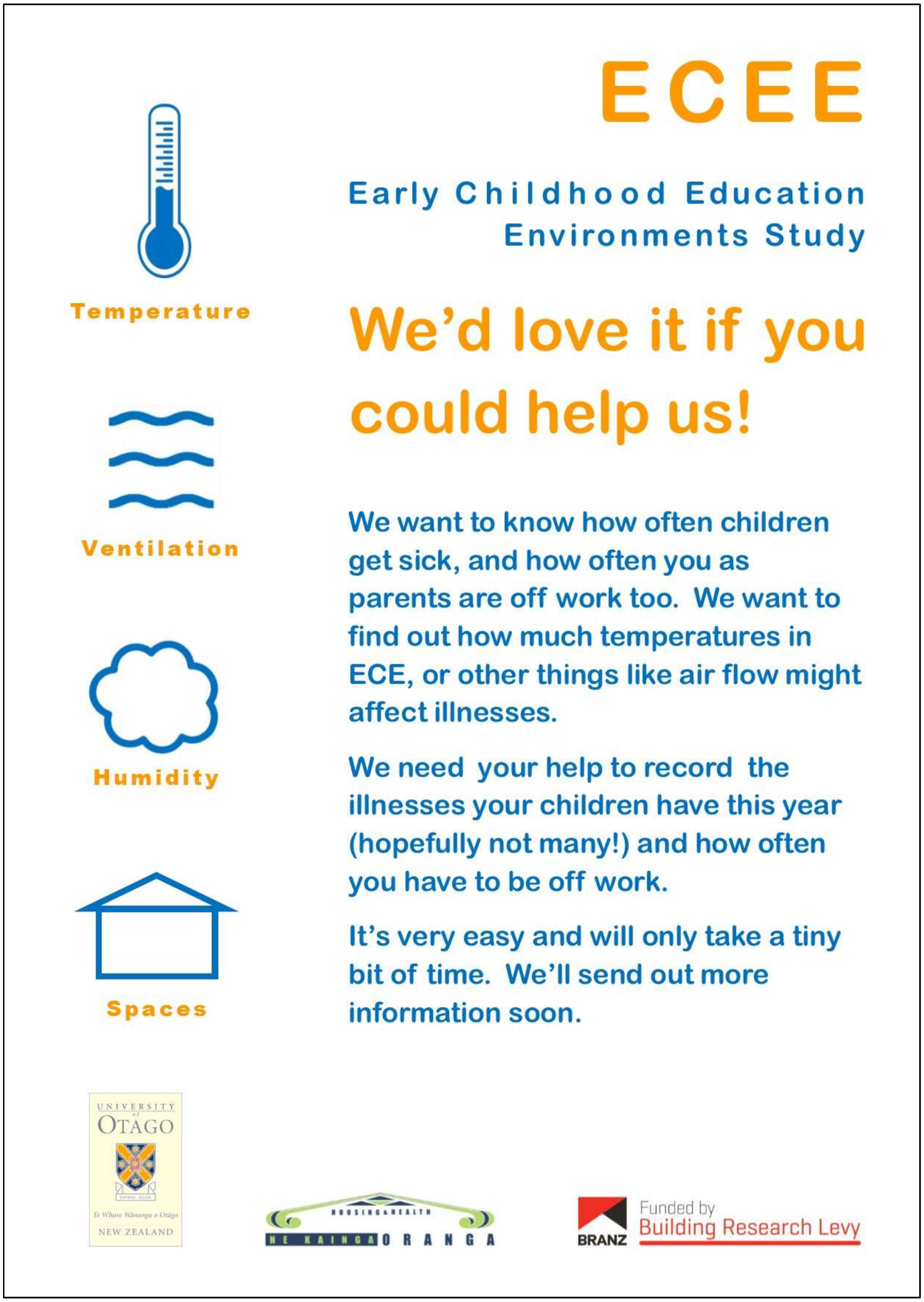
Contact phone __________________________

____________________________________ ____________

Signature *Date*

Appendix 8: Childcare centre poster

Figure 56: Poster advertising the study to parents



Appendix 9: Enrolment pack for parents

Figure 57: Invitation to parents (A5, front of enrolment pack)

ECEE

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

The Early Childhood Education Environments Study

We'd love it if you could help us!

We want to know how often children get sick, and how often you as parents are off work too. We want to find out how much temperatures in ECE, or other things like air flow might affect illnesses.

It only takes a little bit of time (like half an hour over the next six months). Just fill out the enrolment form in this pack and drop it back to the centre. This week would be great. Enrolments close on the 26th May.

BRANZ Funded by Building Research Levy

HOUSING & HEALTH
HE KAINGA ORANGA

Figure 58: How the study works – the quick version (A5)

ECEE

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

How the study works – the quick version

Every week your centre sends us a note to say which children in the study have been away sick.

The first time your child is away sick, we'll give you a call. We'll ask a few background questions and show you the ECEE website. It takes about 15 mins.

Any other time your child is off sick you just login and answer some very quick questions. It takes about 3 minutes. (If the internet doesn't work for you, we can call you.)

If you forget we'll send a text and email to remind you. The study finishes in December.

Figure 59: Parent information

ECEE

Early Childhood Education Environments Study

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

The ECEE Study is a first in New Zealand and we're really keen to have as many children and parents enrolled as we can. The study won't take much of your time – just 15 mins on the phone the first time your child is sick, then for the other times your child is sick about 2-5 minutes to pop the details on a confidential website. That's until December, when the study finishes.

Most New Zealand children are enrolled in some kind of Early Childhood Education (ECE). Good quality ECE is good for children, and parents need to be able to work, so childcare is important.

We have minimum standards for temperature, space and hygiene facilities, but we also know that children attending ECE often get sick. Some of this is just a matter of mixing with others and encountering some illnesses for the first time. The spaces children are in may matter too though, and that's what this study is about.

There are still things we don't know about how often children attending ECE get sick, why and what with, and how often parents have to take time off work.

How the study works

From June to December in 2017 we'll be measuring temperatures and humidity at the childcare centre your child attends.

If you agree to enrol your child we'll be asking you to enter information in a confidential website when your child is ill. We'll only need you to enter information if your child is ill enough to be away from childcare.

Every week your centre will send us a note to say who was away sick. The first time your child is ill we'll call you'll text us, and then we'll call you back and talk you through the website. The first time there will also be some questions about your child's normal health and about your household.

After that it's just questions about the illness – what were the symptoms, how many days sick, who else got sick in the household? It takes about 2 – 5 mins for the questions. At the end of the study we'll analyse the information to see if there's anything about the environments in childcare that seem to be affecting children's health.

BRANZ Funded by Building Research Levy

HOUSING AND HEALTH
HE KAINGA ORANGA

Figure 59 (continued): Parent information p2

Keeping your information private and secure

The University of Otago will keep your information private and confidential. The information from the study that is made public will only be about environmental conditions and illnesses – there won't be any names or childcare centres identified. The website will be confidential, but even there your child's name and address won't be included – only a study number. The enrolment details with your child's name, age and address will be kept separate and secure, not on the website.

About the study team

Mike Bedford is an ECE health and design specialist with a Master of Public Health. Mike has worked with the ECE sector for 25 years, much of that time with Wellington Regional Public Health. Mike has run approximately 150 interactive lectures and workshops on ECE health and design. Mike is currently undertaking ECE health doctoral research with He Kainga Oranga, University of Otago, Wellington and this study is part of that research. Mike is keen to see more New Zealand research to support healthy environments for children.

Who to contact

For most questions, text Mike on [phone number], or ph 0800 [phone number], or email Mike at [email address].

The lead PhD supervisor for this research is Lucy Telfar-Barnard.
Lucy can be contacted at [phone number].

If you want to talk to someone who isn't involved with the study, you can contact an independent health and disability advocate on:

Phone: 0800 [phone number] Fax: 0800 [phone number]
Email: [email address]

The study has the approval the Ministry of Health's health and disability ethics committee (HDEC). They can be contacted on 0800 4 ETHICS, email: hdecs@moh.govt.nz

Figure 60: Child enrolment form

ECEE

Office use only
Study number
Centre number

Enrolment Form

We need some details from you so we know who to contact.

We can only enrol one child per family, so if you have two children at the same centre only enrol the younger child over two years old. If there are twins you'll need to choose one for the study.

Your Child's Surname ______________________________

Your Child's Given Names ______________________________

Your Child's Date of Birth ______________________________

Your Child's usual home address ______________________________ *Street and number*

______________________________ *Suburb*

Your name ______________________________

Relationship to your child (mother, father, auntie…) ______________________________

Your daytime phone ______________________________

Your cell phone ______________________________

Your email ______________________________

Other parent / caregiver name ______________________________

Relationship to your child (mother, father, auntie…) ______________________________

Daytime phone ______________________________

Cell phone ______________________________

Thank you. Now we need you to sign the panel on the back of the form to say you're happy for you and your child to be enrolled.

Please note that if your child normally attends another Early Childhood Education Service as well as this one we won't be able to enrol them for this study.

Please turn over

Figure 59 (continued): Child enrolment form p2

I ____ consent for myself and
Full name

my child__________________________________ to take part in the ECEE study
Full name

I've read the information about this study and I've had time to consider my response and ask questions about the study. I understand that enrolling my child is voluntary, and that the identity of my child and others in my household will be kept private to the study team. Everyone in the study will be given a summary of the study results, but when information from the study is made available or published it will not name anyone in the study or any individual Early Childhood Education Services. I can request the information collected about my child at any time.

I understand that I may withdraw my child from the study any time I want to.

> If I withdraw my child from the study, I'm happy to have the information collected about my child (up to the point when I withdraw) still used in the study.
>
> Yes ☐ No ☐

I'm happy to be contacted by the research team the first time my child is away sick.

____ ______________
Signature *Date*

Figure 61: Contact information for parents (A5)

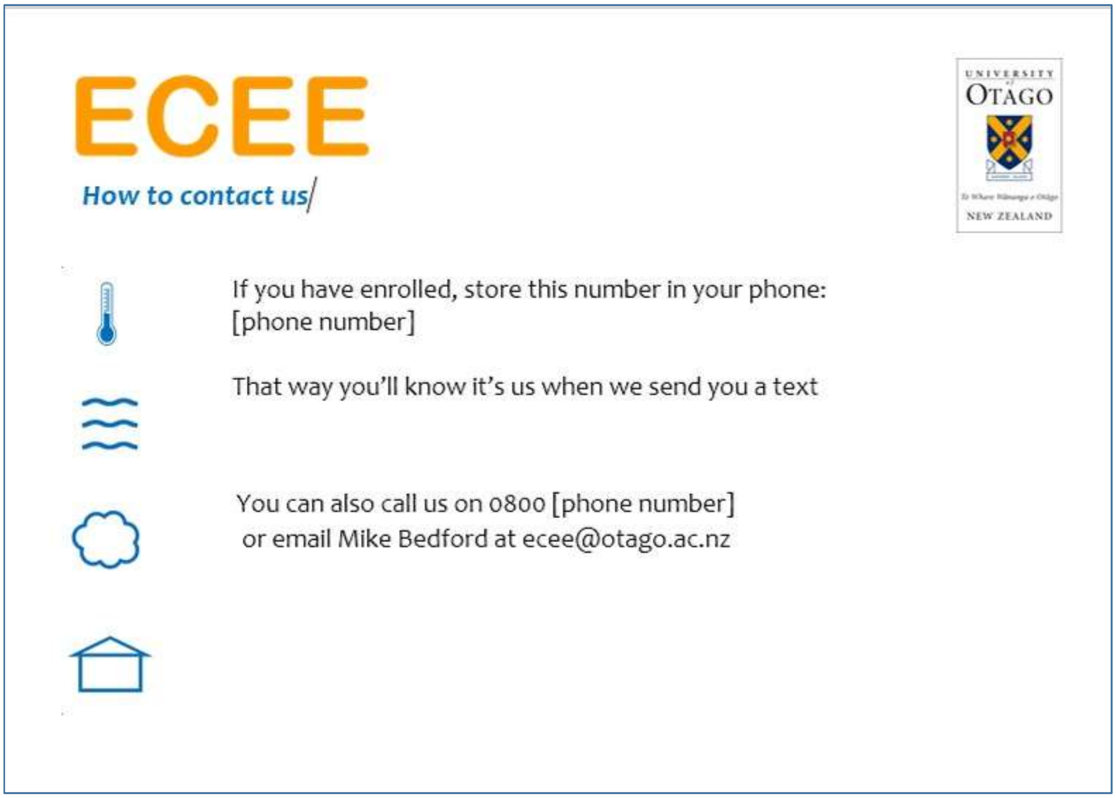
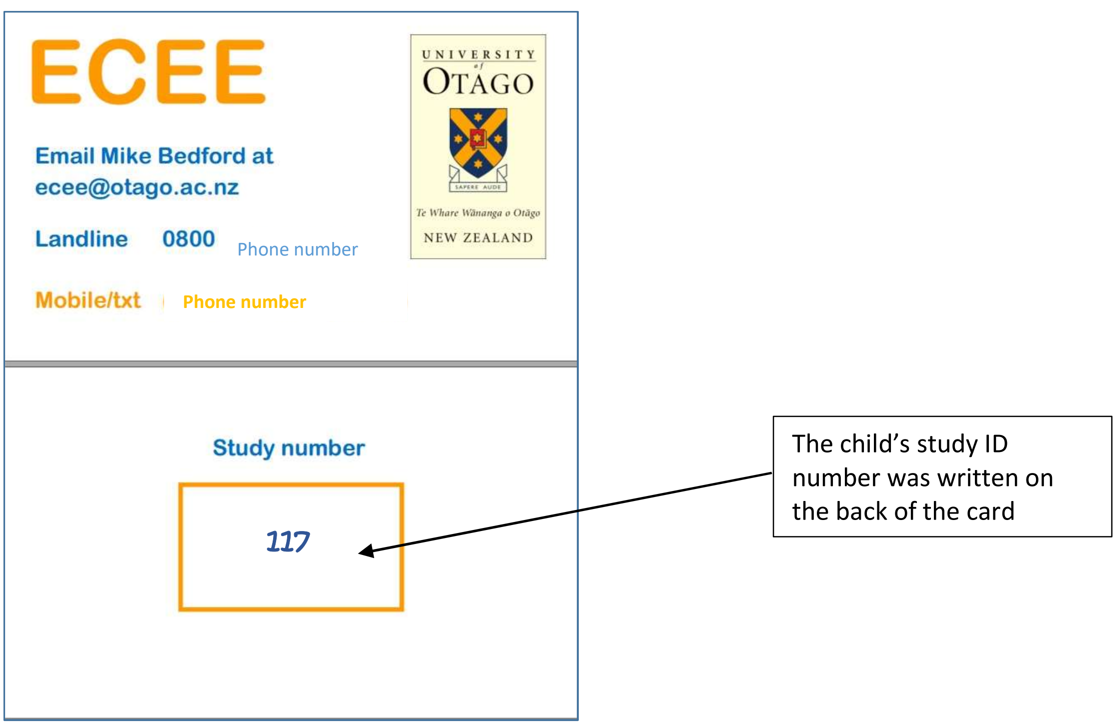
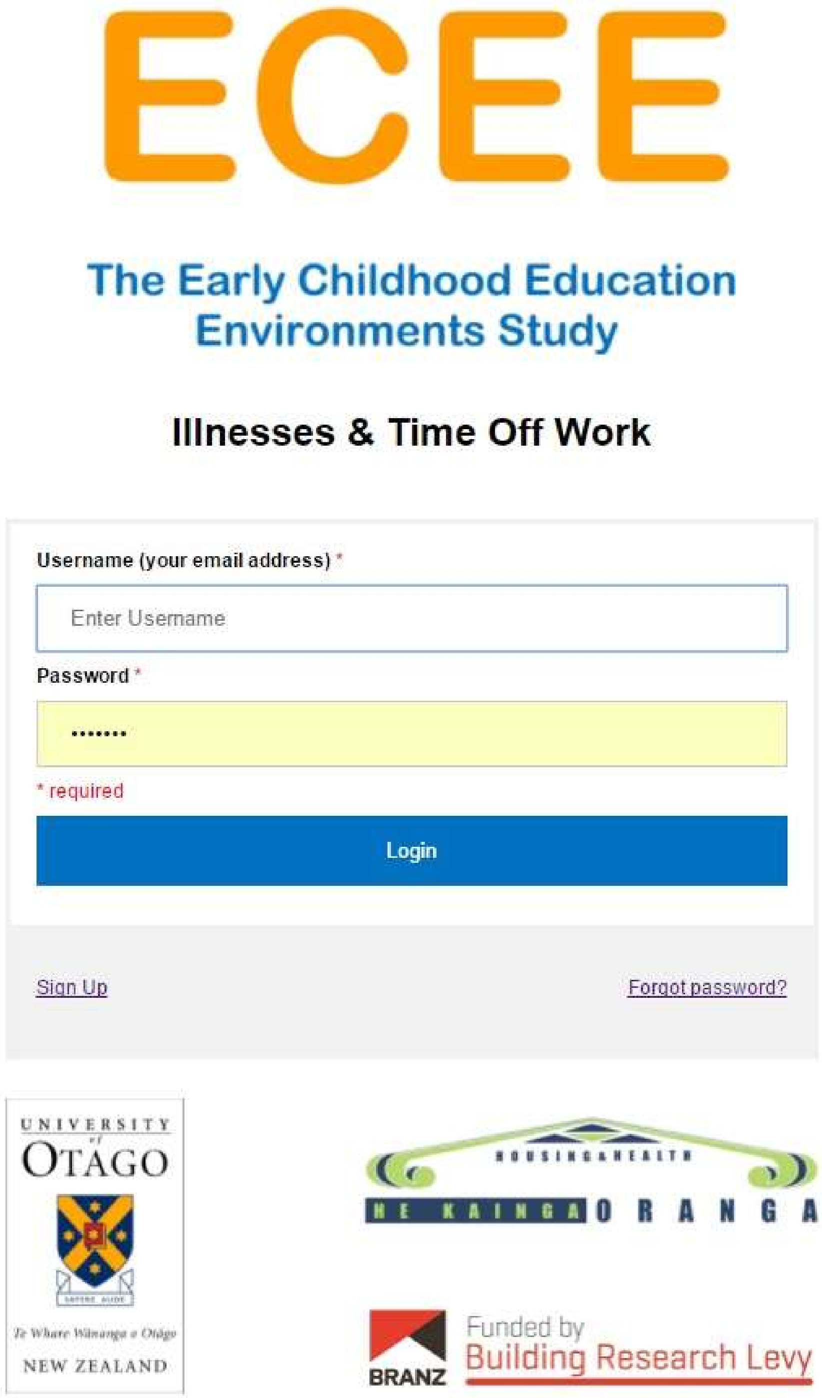


Figure 62: Contact and ID number card (buisness card size)



Appendix 10: Website pages



THE EARLY CHILDHOOD EDUCATION ENVIRONMENTS STUDY

Sign Up

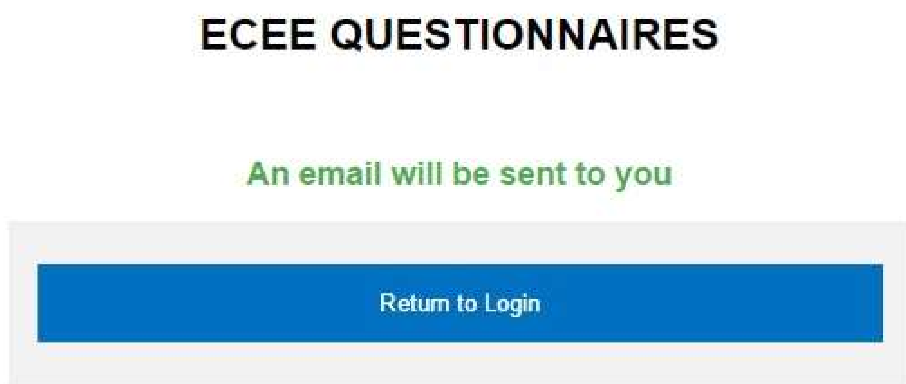
Enter your email address to register.

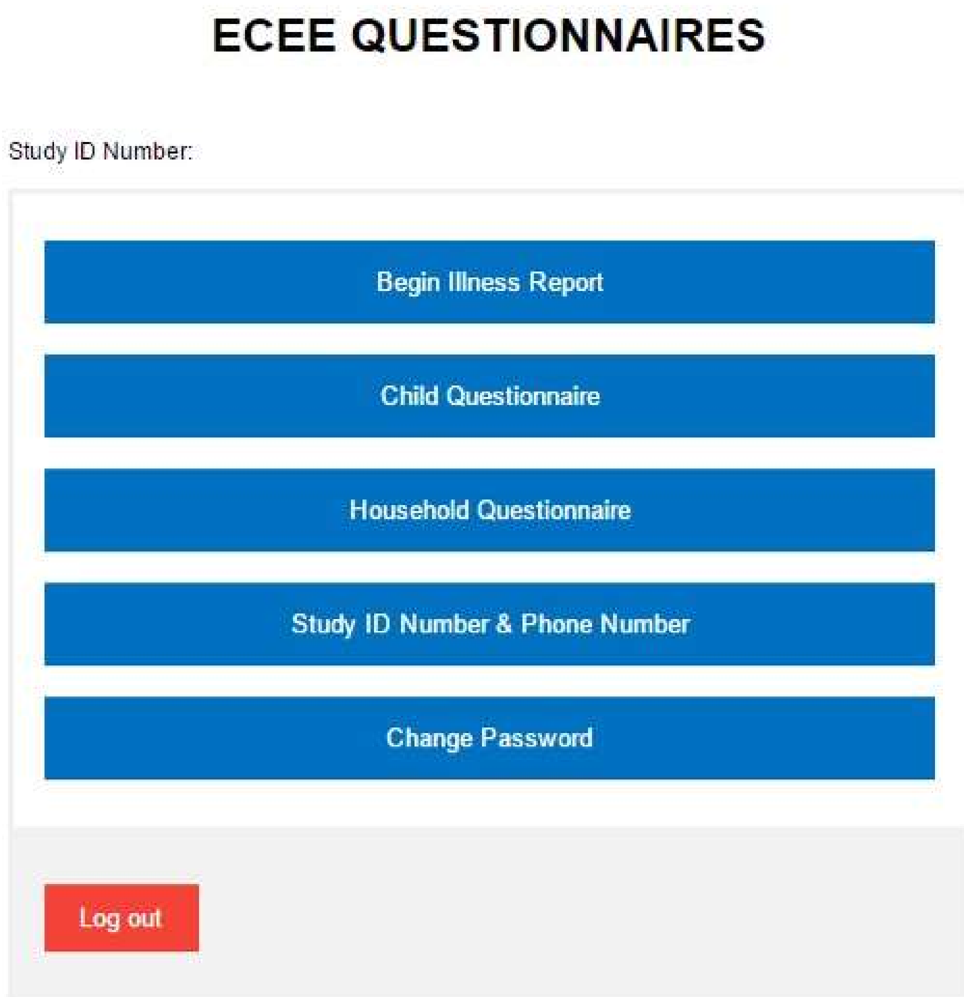
Email Address

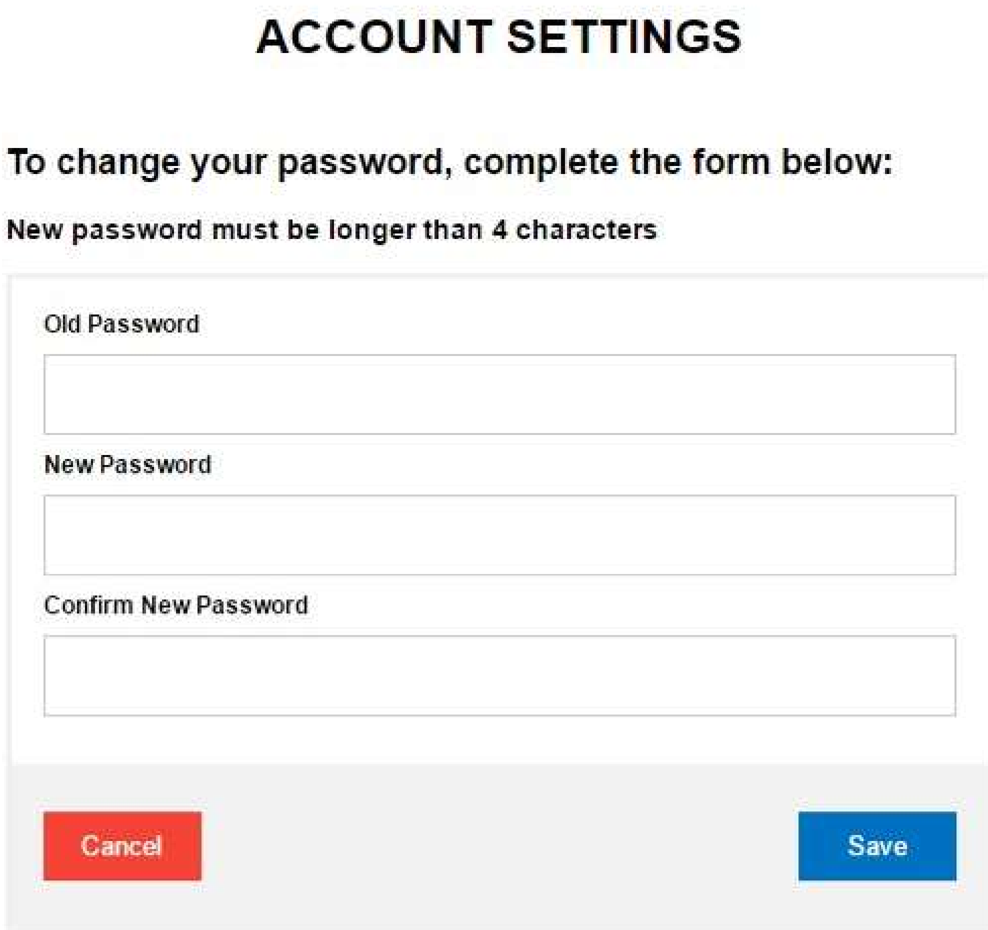
Enter your email address

Submit

Cancel


ECEE QUESTIONNAIRES
An email will be sent to you
Return to Login


ECEE QUESTIONNAIRES
Study ID Number:
Begin Illness Report
Child Questionnaire
Household Questionnaire
Study ID Number & Phone Number
Change Password
Log out



ACCOUNT SETTINGS

To change your password, complete the form below:

New password must be longer than 4 characters

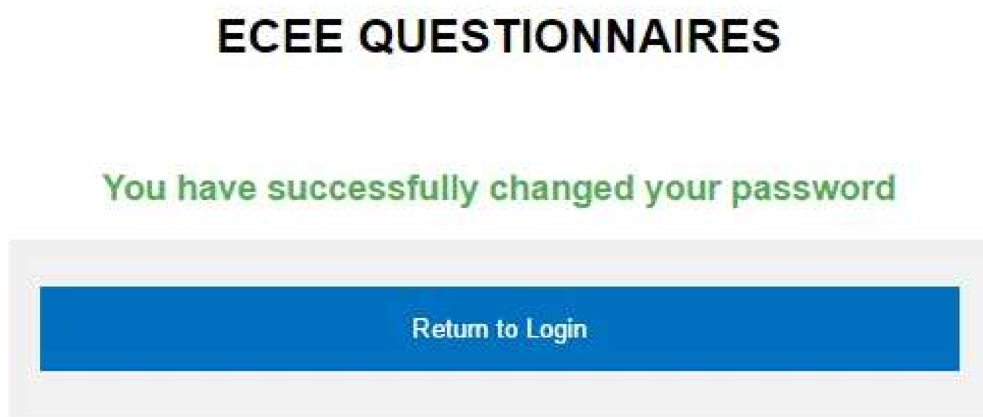
Old Password

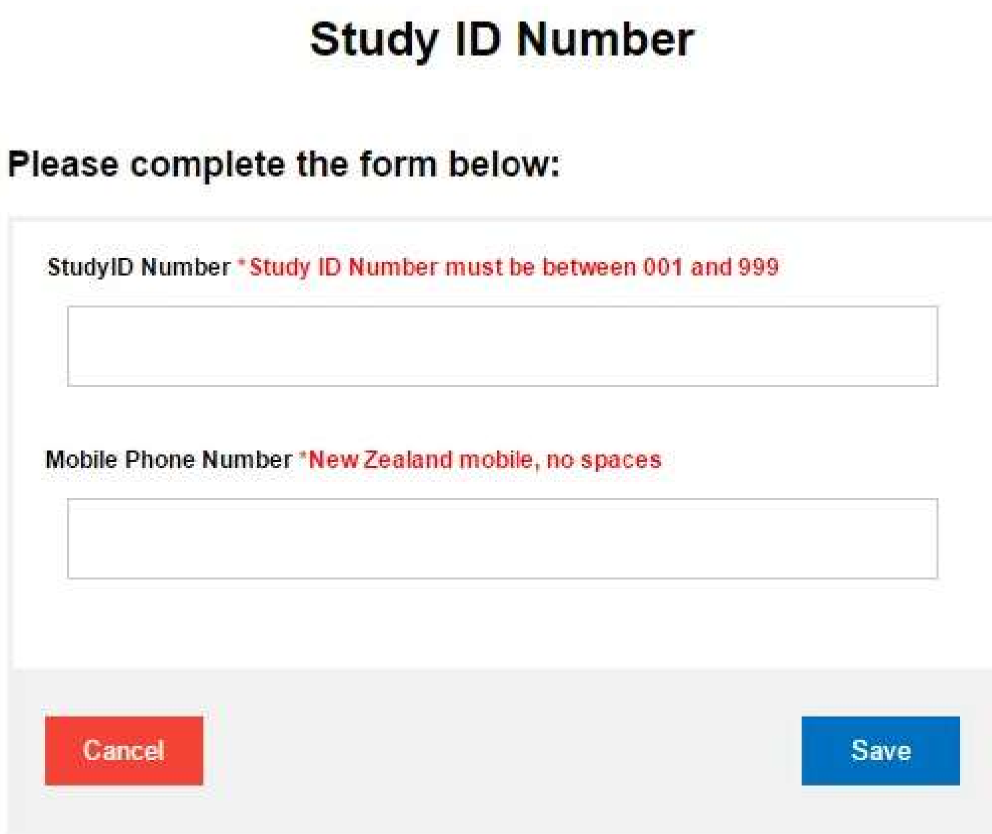
New Password

Confirm New Password

Cancel

Save


ECEE QUESTIONNAIRES
You have successfully changed your password
Return to Login



Study ID Number

Please complete the form below:

StudyID Number *Study ID Number must be between 001 and 999

Mobile Phone Number *New Zealand mobile, no spaces

Cancel

Save

CHILD QUESTIONNAIRE

Child Questionnaire

Which ethnic group(s) does your child belong to?
(You can choose more than one)

- ☐ NZ European
- ☐ Maori
- ☐ Samoan
- ☐ Cook Island Maori
- ☐ Tongan
- ☐ Niuean
- ☐ Chinese
- ☐ Indian
- ☐ Other (such as Dutch, Chinese, Tokelauan)

If other, please describe below:

Did your child regularly attend an early childhood education service (childcare, Playcentre, Playgroup, Kohanga Reo, home-based childcare, kindergarten) before they were two years old?

- ○ Yes
- ○ No

If yes, how old were they when they first attended?

Months old

- ☐ Not sure

How would you describe your child's health at the start of this research?

- ○ Excellent
- ○ Very good
- ○ Good
- ○ Fair
- ○ Poor

Has your child had any of these illnesses in the last 12 months?

Illness				If YES, about how many times?
Ear infection	No	Yes	Not Sure	
Chest infection	No	Yes	Not Sure	
Colds	No	Yes	Not Sure	
Flus	No	Yes	Not Sure	
Diarrhoea	No	Yes	Not Sure	
Vomiting	No	Yes	Not sure	
Croup	No	Yes	Not Sure	

Has your child ever had wheezing or whistling in the chest?

- Yes
- No

How many 'attacks' of wheezing has your child had in the last 12 months?

- None
- 1 to 3
- 4 to 12
- More than 12

Has your child ever had asthma?

- Yes
- Suspected
- No
- Can't remember / Don't know

Has your child ever received a puffer? (asthma inhaler)

- Yes
- No
- Can't remember / Don't know

Cancel

Save

HOUSEHOLD QUESTIONNAIRE

Household Questionnaire

How many bedrooms are there in the house your child lives in most of the time? (include any room with beds in it)

Number of bedrooms

How many people normally live in the house

Number of people

Does anyone normally smoke inside the house?

- Yes
- No

Are there any other children in the house attending early childhood education (childcare, kindergarten, Playcentre, Playgroup, Kohanga Reo, home-based childcare, kindergarten)

- Yes
- No

If yes, how many children?

Are there any children in the house attending school?

- Yes
- No

If yes, how many children?

Was your house ever colder than you would have liked during the last winter (June to September)?

- Yes, always
- Yes, often
- Yes, sometimes
- No
- We didn't live here last winter

Does your home smell damp or musty?

- Yes, always
- Yes, often
- Yes, sometimes
- No

Have you noticed mould on walls, living areas of your home, bedrooms, kitchen or lounge during the past year?

- Yes, always
- Yes, often
- Yes, sometimes
- No

Was your house ever so cold that you could see your breath inside during the last winter (June to September)?

- Yes, always
- Yes, often
- Yes, sometimes
- No
- We didn't live here last winter

Was your house ever so cold that you shivered inside during the last winter (June to September)?

- Yes, always
- Yes, often
- Yes, sometimes
- No
- We didn't live here last winter

In this household, is any parent of guardian of your child a holder of a community services card?

- Yes
- No

Note: This question is only to check that we have a representative sample (a good mix) of Hutt Valley residents.

What was your household's income before tax in the last year?

- Up to $20,000
- $20,001 to $40,000
- $40,001 to $60,000
- $60,001 to $80,000
- $80,001 to $100,000
- $100,001 to $120,000
- $120,001 to $140,000
- $140,001 to $160,000
- $160,001 to $180,000
- $180,001 or more
- Don't know
- Would rather not say

Note: This question is only to check that we have a representative sample (a good mix) of Hutt Valley residents.

Cancel

Save

ILLNESS AND ABSENCES QUESTIONNAIRE

Start of Illness

Event Number: 0001

Which day was the first day of your child's illness that they were home sick?

14/06/2017

What were their symptoms?

- ☐ Cough
- ☐ Sore throat
- ☐ Runny nose
- ☐ Aching limbs
- ☐ Tummy ache
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Rash
- ☐ Ear ache
- ☐ Wheezing
- ☐ Fever

☐ If other, please describe below:

Are they still away from the child care centre?

- ○ Yes
- ○ No

Cancel

Save

ILLNESS AND ABSENCES QUESTIONNAIRE

Start of Illness

Event Number: 0001

Which day was the first day of your child's illness that they were home sick?

14/06/2017

What were their symptoms?

- ☐ Cough
- ☐ Sore throat
- ☐ Runny nose
- ☐ Aching limbs
- ☐ Tummy ache
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Rash
- ☐ Ear ache
- ☐ Wheezing
- ☐ Fever

☐ If other, please describe below:

Are they still away from the child care centre?

- ◉ Yes
- ○ No

Thanks. We'll contact you in a week to see how long it lasted, and whether anyone else in the family got sick.

Cancel

Save

If ‘No’ - child is not still away sick, screen shows…

ECEE QUESTIONNAIRES

That’s great, please complete the next few questions and then we’re all done for now.

Next

END OF ILLNESS QUESTIONNAIRE

End of Illness

Event Number: 0001

What were their symptoms?

- ☐ Cough
- ☐ Sore throat
- ☐ Runny nose
- ☐ Aching limbs
- ☐ Tummy ache
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Rash
- ☐ Ear ache
- ☐ Wheezing
- ☐ Fever

☐ If other, please describe below:

Did they go to a GP (including After-Hours Doctor), or to the hospital?

GP	○ Yes	○ No
Hospital	○ Yes	○ No
Was there a diagnosis?	○ Yes	○ No

If you answered YES, what was the diagnosis?

If you're not sure, text (Phone number or phone 0800 ECSTUDY to talk to someone from the study team.

Have you or your partner been off work because of your child's illness?

- Yes
- No

How many days were you off work because of your child's illness?
(caring for this child or you caught the infection, but not extra time caring for other children)

How many days was your partner off work because of your child's illness?
(caring for this child or you caught the infection, but not extra time caring for other children)

How many other people in the house were sick *with the same illness?*

Apart from your child in the study, how many other people (including yourself, other adults or children) in your household were sick with this illness? If you're not sure, text (Phone number or phone 0800 ECSTUDY to talk to someone from the study team.

What was the last day your child was unwell?

14/06/2017

How many days were they sick? (Counting weekend days as well)

How many days were they away from the centre?

Thanks! No more questions for this illness, but if you'd like one of the research team to contact you to discuss anything please text Phone number and we'll call you back.

Cancel

Save

ILLNESSES AND ABSENCES QUESTIONNAIRE

Welcome back!

Event Number: 0002-0001

Are they still away from the childcare centre?

- (•) Yes
- ( ) No

If you answered YES, did they go to a GP (including After-Hours Doctor), or to the hospital?

GP	( ) Yes	( ) No
Hospital	( ) Yes	( ) No

That's a long time. We hope you're coping OK. When you have a moment for a quick phone conversation, please text Phone number and we'll call you back.

Cancel

Save

ECEE QUESTIONNAIRES

Forgot your password?

Enter the email address you used to register. We'll send you an email with your username and a link to reset your password.

Email Address

Enter your email address

Submit

Cancel

If you still need help, text Phone number or phone 0800 ECSTUDY to talk to someone from the study team.

Appendix 11: Childcare centre Phase 1 questionnaire

Centre Name ______________________________

Centre Address ______________________________

Contact name ______________________________

Contact phone ______________________________

Interview date ______________________________

Interview by ______________________________

Tags required _____

Tag locations ______________________________

____

Tag fixing required ______________________________

____

Probable available cohort ______________________

Activity area ____

1 Maximum number of children using this space at one time _________

2 Age range _________

3 How many teachers are normally in this space? _________

4 How many other adults – administrative, cooking, parent help are normally in this space? __________

5 Is there a minimum temperature you aim for in this activity space? Y/N

6 If yes, what is the minimum temperature you aim for? __________

7 Heating system

Heating system	Heat pump	Main/Secondary
	Infra-red	Main/Secondary
	Fan heater	Main/Secondary
	Gas – flued	Main/Secondary
	Gas – unflued	Main/Secondary

Other heating system ____

8 Heating system observed description

____

____

____

9 Do you think the heating system is effective (does it achieve the temperature you want)?

Poor 1 2 3 4 5 Excellent

9a Comments

____

10 Do you think the heating system is efficient (good heating for the power cost)?

Poor 1 2 3 4 5 Excellent Not known

10a Comments

____

11 Is there a mechanical ventilation system? Y/N

10a Do staff consider a heat pump to be ventilation? Y/N

12 If yes, please describe

____

____

13 Ventilation system observed description

____

____

____

14 Does this space have an outside door? Y/N

If yes, is it usually open?

a. Every day
b. Most days
c. Occasionally
d. Never

14a Comments

____

15 Does the space have opening windows? Y/N

If yes, do you open the windows?

a. Every day
b. Most days
c. Occasionally
d. Never

15a Comments

____

16 Does the space ever feel damp?

a. Every day
b. Most days
c. Occasionally
d. Never

16a Comments

____

17 Have you noticed condensation on windows in this space?

a. Always on cold days
b. Often on cold days
c. Rarely on cold days
d. Never

17a Comments

____

18 Have you noticed mould in this space in the last 12 months Y/N

19 If yes, please describe ____

____

20 Is this space used as a sleeping space? Y/N

21 Are sleep times programmed for this space? Y/N/NA

22 Are all children (using this space) indoors at programmed sleep times? Y/N/NA

23 How often do parents bring sick children?

a. Very often
b. Often
c. Occasionally
d. Rarely
e. Never

23a Comments

____

24 How often do you need to send children home sick?

a. Very often
b. Often
c. Occasionally
d. Rarely
e. Never

24a Comments

____

25 Do you experience difficulty getting parents to collect sick children?

a. Very often
b. Often
c. Occasionally
d. Rarely
e. Never

25a Comments

____

Hand washing routines

26 Do the children usually wash their hands after toileting?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely

27 Number of hand wash stations observed – toilet area __________

27a Comments

____

____

28 Number of hand wash stations observed – activity areas __________

28 a Comments____

____

29 Do the children usually wash their hands after nose blowing?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely

30 Do the children usually wash their hands before eating?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely

31 Do the children usually dry their hands well after hand washing?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely

32 Do children in this space wear nappies? Y/N

33 If yes, does the nappy change policy require wearing of gloves? Y/N/NA

34 If no, are gloves normally worn for nappy changes?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely
f. NA

35 Do the children usually wash their hands after nappy change?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely
f. NA

36 Do the teachers usually wash their hands after nappy change?

a. Always
b. Almost always
c. Usually
d. Sometimes
e. Rarely
f. NA

37 How often are surfaces around the nappy change pad disinfected?

____

38 How often are containers / objects around the nappy change pad disinfected?

____

39 What is the cleaning or disinfection agent for the nappy change pad?

____

40 What is the cleaning or disinfection agent for tables and general surfaces?

____

41 Do children have their own exclusive ‘comfort’ toys? Y/N

42 Do children have shared soft toys? Y/N

43 If yes, how often are the washed? ______________________________

44 How often is playdough made up?

a. Daily

b. _______ times a week.

c. Every _______ days / weeks.

d. No play dough

44a Comments

____

Sleep Room ____

45 Maximum number of children using room at one time ____________

46 Bed arrangement observations

____

____

____

47 Is the door usually open or closed when in use? Open / closed

48 Is there normally an adult in the room while children sleep? Y/N

48a Comments

_______________ ____

49 Is the heating system the same as the activity area? Y/N

50 Is there an extra heater in the sleep room? Y/N

51 Separate or extra heating system

Heat pump	Y/N
Infra-red	Y/N
Fan heater	Y/N
Gas – flued	Y/N
Gas – unflued	Y/N

Other heating system ___________________________________

52 Is there a minimum temperature you aim for in this room? Y/N

53 If yes, what is the minimum temperature you aim for? ________

54 Do you think the heating system is effective (does it achieve the temperature you want)?

Poor 1 2 3 4 5 Excellent

55 Do you think the heating system is efficient (good heating for the power cost)?

Poor 1 2 3 4 5 Excellent Not known

56 Is there a mechanical ventilation system? Y/N

57 If yes, please describe

____

____

59 Mechanical ventilation system observed

____

____

58 Is there a passive ventilation system other than windows, e.g. a gap or vent in the door?

Y/N

59 If yes, please describe

____

____

60 Passive ventilation system observed

____

____

61 Does the room have opening windows Y/N

If yes, do you open the windows?

a. Every day
b. Most days
c. Occasionally
d. Never

61a Comments

____

62 Does the room space feel damp?

a. Every day
b. Most days
c. Occasionally
d. Never

62a Comments

____

63 Have you noticed condensation on windows in this room?

a. Always on cold days
b. Often on cold days
c. Rarely on cold days
d. Never

63a Comments

____

64 Have you noticed mould in this room in the last 12 months Y/N

65 If yes, please describe ____

____

66 Wet weather outdoor play facility observed

____

____

66 Mould observed

____

____

Appendix 12: Example of centre weekly email – sick children

ECEE Study Friday email week ending 18/8/17

Hi

This is the form for this week's return.

Environment number		1	Total of all children enrolled in Pukeko Room			
Week ending Friday		18/08/2017	Total children in Pukeko Room presumed off sick			
Child Study Number	First name	Surname	Usual hours of attendance each week? (Approx)	Off sick this week?	Still off sick today?	Left the Centre?
213			50			
214			25.5			
215			30			
216			22			
217			32			
218			24			

Kind regards

Mike

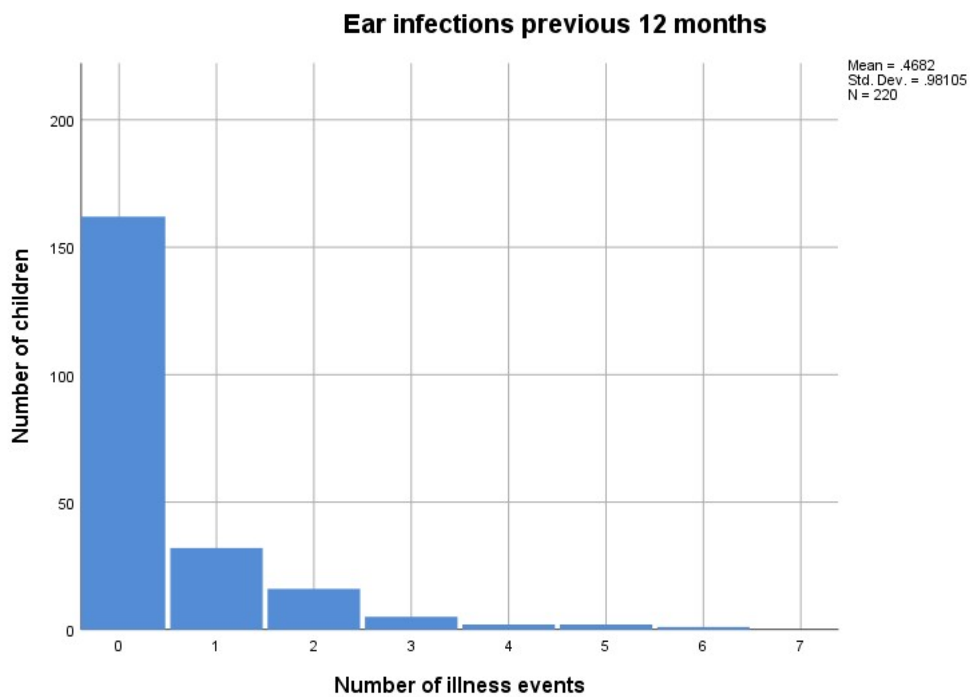
Early Childhood Education Environments Study
He Kainga Oranga – Housing and Health Research Programme
University of Otago, Wellington
0800 ECSTUDY

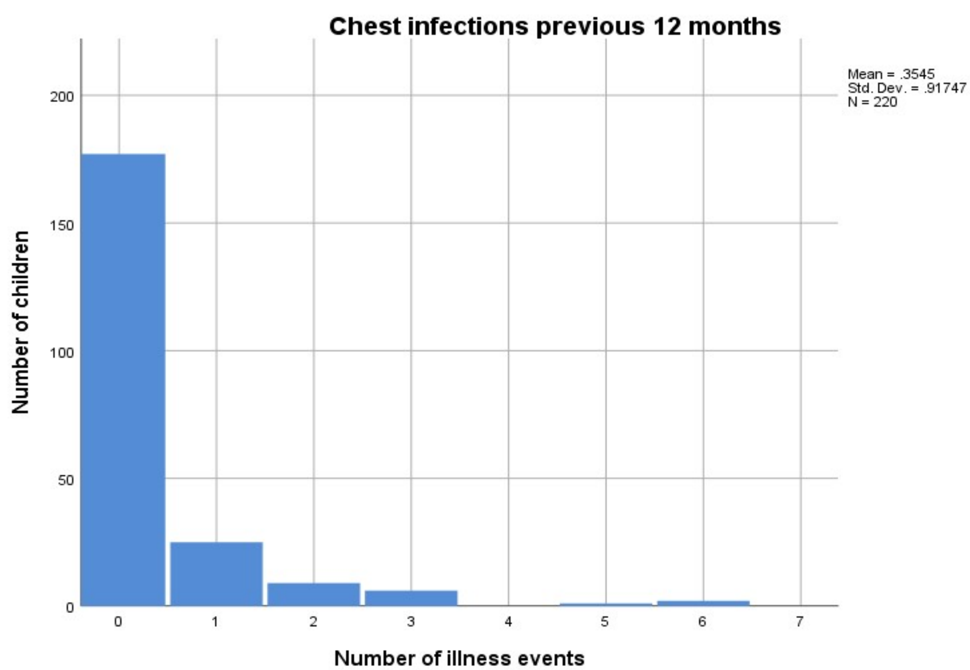
Appendix 13: Tag deployment

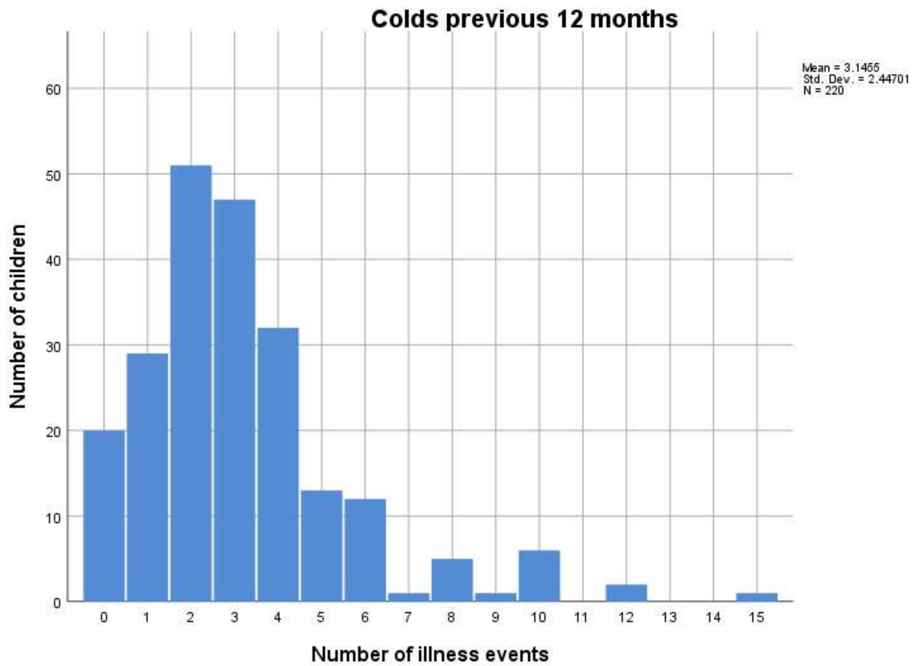
Environment number	Indoor Tag	Location	Installed
1	54	Main activity room	26/05/2017
1	56	Quiet activity and sleep room	26/05/2017
2	52	Main activity room upstairs	26/05/2017
2	55	Staff room	26/05/2017
2A	53	Main activity room downstairs	26/05/2017
3	3	Main activity room	22/05/2017
3	4	Internal activity room and sleep room	22/05/2017
5	32	Main activity room & dining	24/05/2017
5	33	North-east activity room	24/05/2017
5	34	Sleep room	24/05/2017
5	37	North-west room	24/05/2017
6	27	Main activity room	24/05/2017
6	28	West activity room	24/05/2017
6	29	Middle activity room	24/05/2017
6	30	Sleep room	24/05/2017
7	49	Quiet activity and sleep room	25/05/2017
7	50	Main activity room	25/05/2017
7	51	Dining room	25/05/2017
8	47	East activity room	24/05/2017
8	48	West activity room	24/05/2017
9	21	Front activity room	24/05/2017
9	22	Middle activity room	24/05/2017
9	23	Sleep room	24/05/2017
10	59	Main activity room	26/05/2017
10	61	Sleep room	26/05/2017
11	38	Main room	24/05/2017
11	39	East room	24/05/2017
12	68	Back activity room	26/05/2017
12A	67	Front activity room	26/05/2017
12A	71	Sleep room (upstairs)	26/05/2017
13	65	Main activity room	26/05/2017
15	40	Main activity room and library	24/05/2017
15	42	Sleep room	24/05/2017
15	44	Main activity room kitchen side	24/05/2017

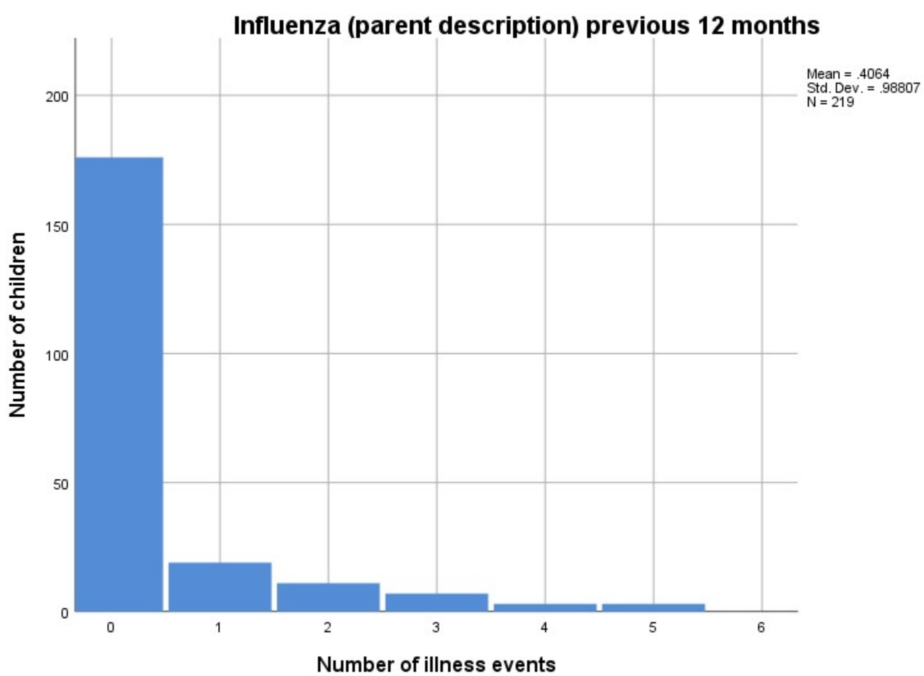
Environment number	Indoor Tag	Location	Installed
16	1	Main activity room west side near exit corridor	22/05/2017
16	2	Main room south wall	22/05/2017
18	7	East activity room	22/05/2017
18	8	Sleep room	22/05/2017
18	10	West activity room	22/05/2017
18	11	Dining room	22/05/2017
18	13	Front activity room	22/05/2017
19	25	Main activity room	24/05/2017
19	26	Sleep room	24/05/2017
20	5	Quiet activity and sleep room	22/05/2017
20	6	Main activity room	22/05/2017
23 & 24	14	House 23 Main activity room	24/05/2017
23 & 24	15	House 23 Front activity room	24/05/2017
23 & 24	18	House 24 Sleep room	24/05/2017
23 & 24	19	House 24 Main activity room	24/05/2017
23 & 24	20	House 24 North activity room	24/05/2017
25	62	Main activity room	26/05/2017
25	64	Quiet / sleep room	26/05/2017
28	73	Main activity room	25/05/2017
29	74	Main activity room	25/05/2017
29	76	Sleep room	25/05/2017
30	77	Main activity room	25/05/2017
30	79	Middle activity room	25/05/2017
30	80	Sleep room	25/05/2017

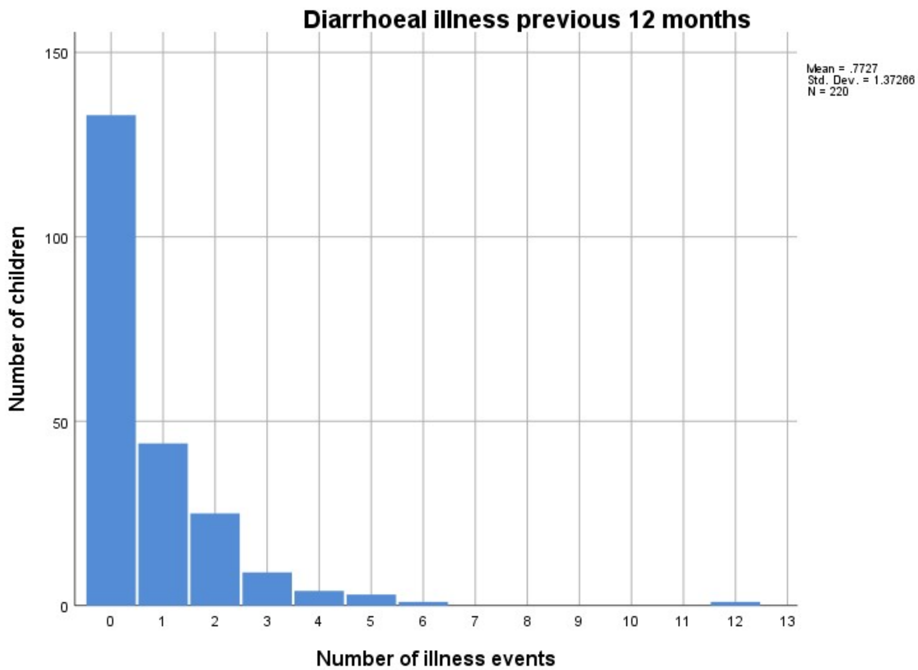
Appendix 14: Prior illness frequency histograms

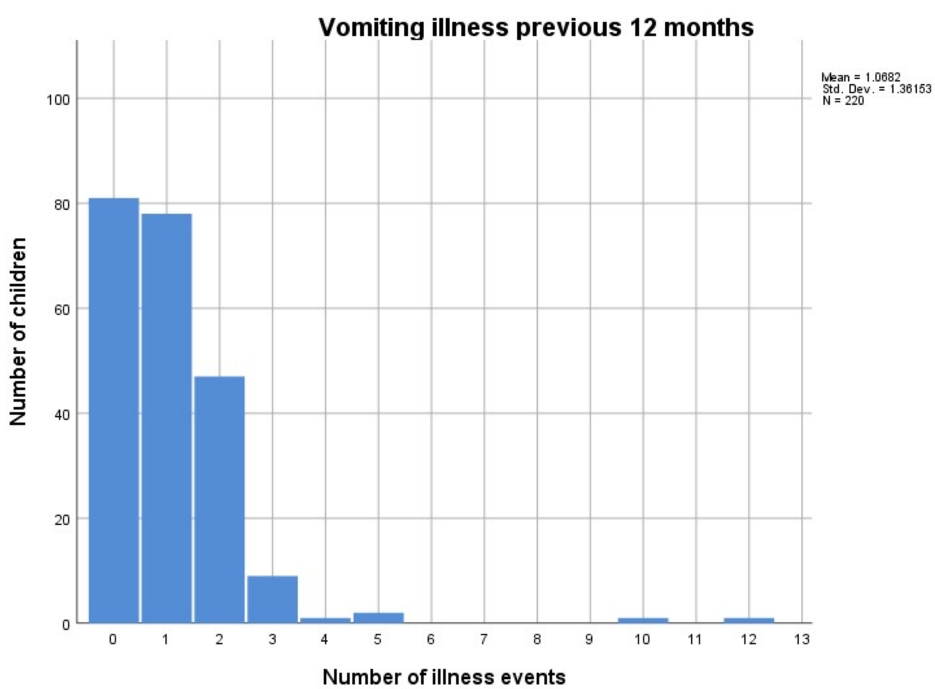


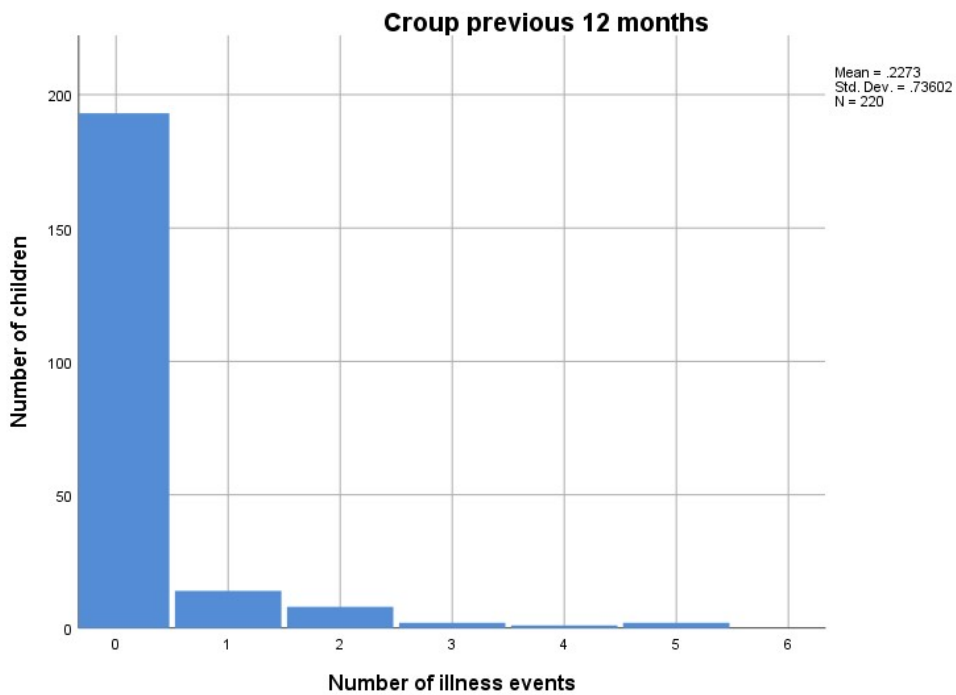



Colds previous 12 months
Mean = 3.1455
Std. Dev. = 2.44701
N = 220
Number of children
0
10
20
30
40
50
60
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Number of illness events


Influenza (parent description) previous 12 months
Mean = .4064
Std. Dev. = .98807
N = 219
Number of children
0
50
100
150
200
0
1
2
3
4
5
6
Number of illness events


Diarrhoeal illness previous 12 months
Mean = .7727
Std. Dev. = 1.37266
N = 220
Number of children
Number of illness events
0
50
100
150
0 1 2 3 4 5 6 7 8 9 10 11 12 13


Vomiting illness previous 12 months
Mean = 1.0682
Std. Dev. = 1.36153
N = 220
Number of children
Number of illness events
0
20
40
60
80
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13


Croup previous 12 months
Mean = .2273
Std. Dev. = .73602
N = 220
Number of children
200
150
100
50
0
0
1
2
3
4
5
6
Number of illness events

Appendix 15: Changes in standard error with inclusion of predictor variables in the GLMM for space per child and child sick days

Environment variable		Fixed effects:					
E1	AIC		Estimate	Std. Error	Exp. Std Error	z value	Pr(>|z|)
m2perchild_min	2929.1	Intercept	0.2705	0.7033	**2.020**	0.385	0.70048
		m2perchild_min	0.7563	0.2792	1.322	2.709	0.00675
m2perchild_min	2926.1	(Intercept)	5.7369	2.398	**11.001**	2.392	0.0167
		m2perchild_min	0.5948	0.258	1.294	2.305	0.0211
		temp_winter_med	-0.2818	0.1202	1.128	-2.345	0.019
m2perchild_min	2869.1	(Intercept)	5.59239	2.41676	**11.209**	2.314	0.0207
		m2perchild_min	0.53778	0.26015	1.297	2.067	0.0387
		temp_winter_med	-0.2714	0.1211	1.129	-2.241	0.025
		hq_mould	0.21853	0.02744	1.028	7.963	1.67E-15
m2perchild_min	2852.4	(Intercept)	5.67252	2.45119	**11.602**	2.314	0.0207
		m2perchild_min	0.52063	0.26371	1.302	1.974	0.0484
		temp_winter_med	-0.27597	0.12282	1.131	-2.247	0.0246
		hq_mould	0.18953	0.02828	1.029	6.702	2.05E-11
		maori_or_pacific	0.2275	0.05201	1.053	4.374	1.22E-05
m2perchild_min	2845.8	(Intercept)	5.78897	2.42211	**11.270**	2.39	0.01685
		m2perchild_min	0.48605	0.26099	1.298	1.862	0.06256
Failed to converge		temp_winter_med	-0.27863	0.12136	1.129	-2.296	0.02168
at tolerance 0.001		hq_mould	0.17123	0.02899	1.029	5.906	3.51E-09
(0.00144016)		maori_or_pacific	0.22545	0.05191	1.053	4.343	1.40E-05
		hq_csc	0.1748	0.05876	1.061	2.975	0.00293
m2perchild_min	2830.1	(Intercept)	5.83252	2.38685	**10.879**	2.444	0.014541
		m2perchild_min	0.53688	0.25766	1.294	2.084	0.037191
		temp_winter_med	-0.26115	0.11968	1.127	-2.182	0.029097
		hq_mould	0.16478	0.02893	1.029	5.697	1.22E-08
		maori_or_pacific	0.23086	0.05218	1.054	4.424	9.69E-06
		hq_csc	0.19889	0.05911	1.061	3.365	7.67E-04
		Ageinyearsatstart	-0.13626	0.03237	1.033	-4.21	2.56E-05
m2perchild_min	2820.7	(Intercept)	6.14668	2.35508	**10.539**	2.61	0.009055
		m2perchild_min	0.4921	0.25446	1.290	1.934	0.053126
		temp_winter_med	-0.25991	0.11799	1.125	-2.203	0.027613
Failed to converge		hq_mould	0.15848	0.029	1.029	5.466	4.61E-08
at tolerance 0.001		maori_or_pacific	0.23412	0.05203	1.053	4.499	6.82E-06
(0.00575156)		hq_csc	0.17885	0.05943	1.061	3.009	0.002619
		Ageinyearsatstart	-0.15522	0.03284	1.033	-4.727	2.28E-06
		ece_before_2yrs	-0.19148	0.05618	1.058	-3.408	0.000654

Appendix 16: Recommendations for the Draft 10 year Strategic Plan for Early Childhood Education

Draft Strategic Plan Goal 1: Quality is raised for children by improving regulated standards

I strongly support this goal, particularly with respect to improved ratios, group sizes, and space per child, and noise reduction. I strongly support the proposal (1.4) to develop comprehensive integrated advice in relation to children's environments. From the findings of the ECEE study I would like to make the following recommendations.

Indoor temperature

Recommendation: The study provided evidence for to support a change in the Education (Early Childhood Services) Regulations for indoor temperatures, returning to the 1990 minimum temperature standard of 18°C at child height.

Ventilation

The current requirement for ventilation in the *Criteria for Licensing, PF12* [231], reads: "Parts of the building or buildings used by children have: Ventilation (natural or mechanical) that allows fresh air to circulate (particularly in sanitary and sleep areas)."
This requirement lacks any measurable criteria for compliance, and the guidance section in the *Criteria for Licensing* contains no technical information for ventilation design.

Recommendation: There is a need for technical advice for air quality and ventilation in ECE Services, and measurable criteria to applied when rooms are occupied.

Compliance

The study showed poor compliance with legal requirements for space per child, minimum temperatures, and ventilation.

Recommendation 1: The licensing of ECE centres needs to include assessment of ventilation systems by a person suitably qualified.

Recommendation 2: ECE centres should be equipped with monitoring devices to provide objective environmental measures, and alerts if conditions are substandard (low temperatures, poor air quality, and excessive noise levels), with data logging for compliance monitoring.

Recommendation 3: Measures of environmental quality need to be part of the regular review of ECE centres, including temperatures, air quality and space per child.

Draft Strategic Plan Goal 3: Investment in our workforce supports excellence in teaching and learning

The ECE teaching environment is high risk for exposure to infections, and while we have to assess the effect of teachers working while sick, it is logical to suggest that this would contribute to infection spread. The Education (Early Childhood Services) Regulations, prohibit teachers from working while infectious, but in practice this regulation is rarely implemented.

The health risk to teachers from the working environment is an employer responsibility, and the sick leave allocation should reflect this for both the teachers and the children. Being forced to work while sick is likely to affect quality of work, and ultimately deter people from being willing to continue to work in that environment.

Recommendation: Teacher sick leave provision needs to reflect risk in an ECE environment, with a greater legislated allocation of sick leave than the minimum for the general workforce. The allocation should be in line with that provided for primary school teachers.

Draft Strategic Plan Goal 5: The early learning system continues to innovate, learn and improve.

At present there is not one full time position for wellbeing in early education in care, in either of the Ministries of Education nor Health. There is no nationally coordinated programme to coordinate advice on ECE wellbeing, that links health and human development science to pedagogy, or seeks to improve wellbeing as a platform for learning.

I recommend that we implement the 2011 recommendations of the Commissioner for Children:

"It is recommended that the Minister of Education and Minister of Health direct their officials, in consultation with other agencies as appropriate, to:

> …set up a process for health sector engagement in policy development, regulation and operational planning for formal non-parental ECS at national and regional levels", [232]

In conjunction with the proposals in Goal 1, I recommend that a centre of research and advice for wellbeing and quality of life in the ECE sector be developed, linking the Ministries of Education and Health, and social services, and aligning with Goal 5.1, "Establish innovation hubs for early learning services". Key components of the work of such a centre need to be:

1 Architecture and building technology that promotes wellbeing.

2 Teacher training in wellbeing, including healthy environments and disease prevention.

General population sick leave provision

As for teachers, all employees who have of young children may face a greater demand on sick leave than they would otherwise. The mandatory sick leave provisions need to be changed to be parent-friendly, allowing a minimum allocation of domestic leave.

If the provision of ‘domestic leave’ rather than ‘sick leave’ is made universal, it would also allow for other situations such as care of the elderly or other dependents, and mitigate against employer discrimination against parents.